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Technical Reference User Manual (TRM)

Measure Savings Algorithms and Cost Assumptions

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Introduction

1.1 Purpose of Technical Reference Manual

This Technical Reference Manual (TRM) provides descriptions of energy efficiency measures implemented by Efficiency Vermont's programs together with all the necessary algorithms and default assumptions for estimating the energy (both electric and fossil fuel) and peak electric capacity impacts. In addition, all parameters required for the application of cost-effectiveness tests (such as loadshapes, costs and lifetimes) are provided.

The manual is made up of *characterizations* which document all assumptions for a particular efficient technology. Within each characterization, there may be one or many specific sets of assumptions that characterize a specific application (e.g. multiple efficiency levels, fuels, capacity ranges, etc.) or technology type (e.g. various LED fixture types) all of which share the same algorithm, but where one or more inputs may be variant.

1.2 Use and Application of the TRM

1.2.1 Claiming Savings and Cost-Effectiveness Calculations

The TRM is the system of record for claiming savings and performing cost effectiveness tests for the efficiency measures and applications characterized and installed within a particular program year.

The primary cost-effectiveness test used by Efficiency Vermont to evaluate the performance of efficiency measures is the *Societal Cost Test* (SCT), as described in the California Standard Practice Manual[1]. A positive cost-effective test result (or screening) is required for overall portfolio, total program, and customer project level screening, with some exceptions for low-income programs, pilots, and new technologies that require heightened program support. Components or measures within a project may be non-cost-effective, particularly if required for health and safety, so long as the project, program or portfolio screens as a whole.

All components needed to perform a cost-effectiveness test are found within the TRM and the calculations are performed through application of a Screening API (Application Programming Interface) accessed through Efficiency Vermont's analysis and tracking system *Tracker*.

1.2.2 Annual Savings Verification

At the end of each program year, a version of the TRM containing all measures that were active at any time during that program year is saved and used as the basis for corroborating Efficiency Vermont savings claims during the annual evaluation of the ratepayer-funded programs in Vermont, referred to as the Savings Verification process.

1.2.3 Portfolio Planning and Evaluation (Demand Resource Plan)

The TRM also provides the basis for first year assumptions within the implementation of portfolio modelling exercises including the Demand Resource Plan, filed every three years. The TRM characterizations generally do not provide documentation of future year adjustments to first year assumptions, though in instances where such adjustments are known (e.g. forthcoming Federal Standard changes) they may be documented and planned for. Therefore where modeling is required for multiple years in to the future, additional assumptions concerning future year changes need to be documented outside of the TRM and within the specific application used for forecasting and portfolio screening.

1.2.4 Forward Capacity Market

Efficiency Vermont is an active bidder into the ISO-New England (ISO-NE) *Forward Capacity Market (FCM)*. The FCM is an annual Auction where bidders commit to the supply of future capacity in exchange for a market-priced payment, with a goal to ensuring that the New England power grid will have sufficient resources to meet future demand. Demand-side efficiency programs that can guarantee the generation of electricity savings during the ISO-NE defined peak period can be included in the market.

The TRM is a major component of the Measurement and Verification (M&V) plan that is required in order to qualify to participate in the FCM auction. Efficiency Vermont submits a new version of the plan with a copy of the active TRM to ISO-NE for review every year.

1.3 Prescriptive v Custom Measures

The primary objective of the TRM is to document the savings assumptions for *prescriptive* measures – i.e. those measures with a high volume and with relatively low per unit savings, where individual custom calculations would be cost-prohibitive, or where the likely variation of savings is low and/or the availability of input data is prohibitive to a custom application of the measure.

However there is a spectrum of “prescriptiveness” across characterizations, ranging from those with a single deemed savings value, to those semi-custom characterizations where multiple inputs are required for each application. The TRM may also be used to document *custom* protocols and/or provide one or more of the key cost-effective test inputs that cannot be collected on site (such as lifetime) for those measures that are evaluated outside of the TRM (e.g. through modeling software, metering etc).

When evaluating which form a particular measure will take, the balance of the cost of implementation against the corresponding potential accuracy of the savings estimate is considered.

1.4 Development and Review Process

The manual is maintained by members of Efficiency Vermont’s Evaluation, Measurement, and Verification (EM&V) department. There are four main scenarios when changes are made to the TRM:

1. New characterizations are created whenever a new technology is ready for implementation and where savings will be claimed through a prescriptive process.
2. Existing measures are updated with new information, e.g. for a Federal Standard or efficient specification update, following publication of new evaluation results that provide an improved basis for existing assumptions, or where new measure implementation methods require additional variable assumptions.
3. Existing measures are updated to fix errors or provide improved clarifications.
4. Reliability updates - Any characterization that has not received any update for three years is automatically included in a review process to check for continued validity, consistency with other measures, accuracy of assumptions and whether any new evaluation results should be considered. Changes arising from the reliability review are activated in the subsequent program year.

1.4.1 Review Processs

Once a characterization draft is complete an initial screening of the measure is completed to assess whether the assumptions lead to a cost-effective application. The measure is then reviewed internally by VEIC EM&V staff, before being sent to the Vermont Public Service Department for review. When all comments are received and resolved, the measure is made *Active* in the TRM on its Effective Date and all prescriptive measures installed from that date will utilize the new assumptions.

1.4.2 Application of Updates

Whenever possible, characterizations are made active after the Internal and External review process described above is complete, such that the new assumptions are applied only for measures installed prospectively. However, when considered appropriate (e.g. to align with the effective date of a specification change, or when fixing a significant error), the characterization change may be made *retroactively* and any prior installation in the present program year will be adjusted accordingly.

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[1] ‘California Standard Proactive Manual, Economic Analysis of Demand-Side Programs and Projects’, October 2001.

Characterization Structure

The TRM contents are organized by Program and then End Use. However where the same technology is supported in multiple programs, and where the characterization methodology and algorithm(s) are similar, some characterizations have been consolidated into one, providing alternative assumptions for each program type where appropriate.

Each characterization is made up of the following components:

1.1 Update Summary

The update summary describes the current characterization's updates from its previous version (if applicable). This will outline specific changes to the characterization, if that is a cost update or efficient condition update.

1.2 Referenced Documents

All referenced documents are listed with a hyperlink to open the document. These may include analysis spreadsheets used to calculate the savings, evaluations, and memos.

1.3 Descriptions

1.3.1 Program Type

The Program Type section will provide the calculation type that is used in the characterization and the program delivery/implementation type. This helps the reviewer understand how the measure is being delivered to customers and how savings will be calculated.

1.3.2 Measure Description

The Measure Description section includes a general description of the measure, how it saves energy, and the specific *reporting category*(s) and delivery mechanism(s) being characterized. It will be clearly stated whether the measure is intended to represent a Market Opportunity (i.e. time of replacement or new construction), Early Replacement, Retrofit or Early Retirement application, and the method of implementation (e.g. Up-, Mid- or Down-stream, Direct Install, or Building Performance Programs). See definitions in section 3.2 and 3.3.

1.3.3 Baseline Efficiencies

The baseline assumptions will be clearly defined. For a Market Opportunity measure the baseline is generally based on one of two approaches: either a minimum code or standard efficiency level, or a market based estimate representing what is most common in the marketplace, often determined through a baseline study.

For Early Replacement , Retrofit and Early Retirement applications the baseline is generally the existing equipment as it is currently operated, or as it would be expected to be operated in the absence of the energy efficiency measure/equipment.

1.3.4 Efficient Equipment

The Efficient Equipment section includes a clear definition of the criteria by which it will be determined whether equipment qualifies as efficient. This may include specific technologies, minimum efficiencies, energy efficiency standards (such as ENERGY STAR or CEE Tiers), or other criteria.

1.4 Algorithms

1.4.1 Algorithm Outputs

The Algorithm section provides mathematical formulas for the impact of the measure on each of the following as appropriate:

1. Electric Demand Savings: calculation of the first year connected load reduction (or penalty). This is used to estimate the Summer and Winter *coincident peak kW* reduction, by multiplying with the coincidence factors from the measure's loadshape. This usually represents the maximum kW reduction associated with the measure, but some loadshapes deliberately assume that it represents the average kW reduction.

2. Electric Energy Savings: calculation of the first year total kWh saved (or penalty) per unit.

3. Fossil Fuel(s) Savings: calculation of first year MMBtu savings (or penalty) or any applicable fossil fuel (natural gas, liquefied petroleum gas (propane), distillate, kerosene, wood (logs, pellets or chips)).
4. Water Savings: calculation of first year water savings (or penalty)

1.4.2 Algorithm Variables

Each variable within an algorithm will be listed and defined. Variables can take the form of Constants, Deemed Values or Inputs:

1. Constants - values that are universal, such as conversion factors that will have the same values in all contexts.
2. Deemed Values - variables for which an average, typical, or representative value has been determined for the measure or application in question. In many cases there may be multiple deemed values provided for different applications, efficiency levels, installation locations etc. Each unique combination of Deemed Values will be screened separately and use a different *Item Code* to track installation; see section 2.8.2 for more information. Each deemed value will have a source reference specifying the basis of the assumption(s). If the values were calculated, the details of the calculation will be provided either in a footnote or in an attached referenced document.
3. Inputs – custom values that are input into the algorithm directly based on information collected onsite or provided on a prescriptive form or invoice. A default value may be provided for instances where the input data is missing or incomplete.

   Depending on the construction of the algorithm and its variables, each measure output may be a single deemed value, multiple deemed values depending on one or more variable, or be a custom output requiring calculation dependent on one or more Inputs.

1.4.3 In Service and Leakage Rates (where applicable)

Many Market Opportunity characterizations include variables to address the likelihood that a purchased measure will end up being installed within the Vermont service territory:

- In Service Rate (ISR): Representing the assumed proportion of all sales that end up getting installed. This is particularly important for measures that are provided free or at low cost to the customer.
- Leakage Rates: Representing the assumed proportion of sales through the program that are installed outside of the Vermont service territory and so are ineligible to be counted towards efficiency goals.

1.4.4 Mid Life Baseline Adjustment (where applicable)

In some characterizations, it is appropriate to apply a mid-life adjustment to the kWh and/or MMBtu savings at some point within the life of a measure. This affects the lifetime savings of the measure as well as the Net Present Value. Possible scenarios requiring this adjustment are:

1. Early replacement measures where the first X years' savings are from the existing equipment to the new efficient equipment while the following Y years' savings are from a hypothetical new baseline unit to the efficient equipment.
2. Situations where the baseline alters one or more times during the life of the efficient measure, resulting in a change to the assumed baseline efficiency, for example, incorporation of the impact of EISA lighting standards on baseline replacement lamp efficacies within the lifetime of an LED installation.

When such an adjustment is required, the characterization will specify the adjustment percentage (i.e. 'new savings after adjustment' / 'first year savings') plus the timing of the adjustment (either number of years from installation or to occur in a specific future year).

1.5 Loadshapes

Every measure with electric savings has a loadshape provided. Each loadshape is made up of six percentage values; four energy periods (totaling 100%) that are multiplied by the first year electric energy savings and applied to a unique set of *avoided costs* (for Winter Peak, Winter Off-Peak, Summer Peak and Summer Off-Peak), and two *coincidence* *factors* (Winter and Summer) corresponding to the percent of kW savings that is concurrent with ISO-NE's defined coincident peak periods. Loadshapes also include an assumed hours of use which is used in determining the loadshape, but may be different to the hours used in a measure's savings calculation.

Active Efficiency Vermont loadshapes can be found here.

1.5.1 Efficiency Vermont Avoided Cost Period Definitions

As of January 1, 2016, Efficiency Vermont is using the following avoided costs energy periods based on the Avoided Energy Supply Costs in New England: 2015 Report prepared for the Avoided-Energy-Supply-Component (AESC) Study. The coincident peak periods are based on ISO New England performance hours for the forward capacity market.

Winter Peak Energy: 7AM - 11PM, weekdays, October to May;

Winter Off-Peak Energy: 11PM - 7AM, weekdays, all weekend hours, October to May;

Summer Peak Energy: 7AM - 11PM, weekdays, June to September;

Summer Off-Peak Energy: 11PM - 7AM weekdays, all weekend hours, June to September.

Summer Gen. Capacity: 1PM-5PM, weekday, non-holiday, June-August

Winter Gen. Capacity: 5PM-7PM, weekday, non-holiday, December-January

1.6 Net Savings Factors

The characterization provides the *Gross Savings* estimate, i.e. the estimated savings experienced at the customer's meter as a result of the energy efficiency measure. To complete the cost effectiveness tests, it is necessary to convert the Gross Savings into *Net Savings*, i.e. the estimated savings at generation and attributable to the program. Net Savings is calculated as follows:

$NetkWh = \sum(netkWh_i)$

$netkWh_i = \Delta kWh * (1+LLF_i) * (FR + SPL - 1) * RPF_i$

$NetkW_j = \Delta kW * (1+LLF_j) * (FR + SPL - 1) * CF_j$

Where:

$netkWh_i$ = kWh energy savings at generation-level, net of free riders and persistence, and including spillover, for period *i* (Winter On-Peak, Winter Off Peak, Summer On-Peak and Summer Off-Peak)

i = subscript used to denote variable energy rating periods (Winter Peak, Winter Off-Peak, Summer Peak, Summer Off-Peak).

ΔkWh = gross customer annual kWh savings for the measure

LLF_i = line loss factor for period *i*. The Line Loss factor represents the marginal electricity losses from the generator to the customer – expressed as a percent of meter-level savings.

FR = *Freeridership factor*, as presented in the measure characterizations. The Freeridership factor is equal to 1 minus the percent freeridership. For example, if it is assumed that 10% of measure installations are freeriders, FR will be equal to 0.9.

SPL = *Spillover factor*, as presented in the measure characterizations. The Spillover factor is equal to 1 plus the percent spillover. For example, if it is assumed that a measure has 5% spillover, SPL will be equal to 1.05.

RPF_i = rating period factor for period *i* [as provided by the loadshape]

$netkW_j$ = kW demand savings, net of free riders and persistence, and including spillover, for season *j*

j = subscript used to denote variable seasonal peaks (Summer or Winter).

ΔkW = gross customer connected load kW savings for the measure

LLF_j = line loss factor for seasonal peak *j*

CF_j = *the percent of kW savings that is concurrent with Vermont's seasonal peak, for season j [as provided by the loadshape]*

1.6.1 Line Loss Factors

All of the parameters above except *Line Loss factors (LLF)* are provided in each measure characterization. The LLFs do not vary by measure, but by costing period, and are provided in the following table[1]. Note the "Including PTF" values are used in the Net Savings calculation above:

Distribution Line Loss Values - Efficiency Vermont

Marginal Losses by Costing Period	not including PTF*	Including PTF
Winter Peak	11.8%	14.8%
Winter Off-Peak	9.8%	12.3%
Summer Peak	11.9%	15.0%
Summer Off-Peak	9.5%	11.9%

Average Losses at Peak Hour	not including PTF	Including PTF
Winter	9.0%	11.3%
Summer	8.9%	11.2%

*PTF means pooled transmission facility

Values "including PTF" are to be used in Net Savings calculations to reflect the impact on power generation.

1.6.2 Measure Codes and Item Codes

Each characterization will have one or more associated *Measure Codes*, used to identify the general technology. A single measure code may represent many different (but related) specific technologies, and they all will share the same Net to Gross Factors (Freerider and Spillover rates) within each program *Track*.

Measure codes are eight-character alpha-numeric codes, consisting of the following:

- The first three digits represent the end use being impacted by the measure.
- The remaining five digits represent the measure, application and/or efficiency level as appropriate.

For example: CKLC3WRP

CKL: Cooking and Laundry end use

C3: CEE Tier 3

WRP: Clothes Washer

For example: LFHEXLED

LFH: Lighting Hardwired Fixture end use

EX: Exterior

LED: LED Fixture Type

Each unique output from a characterization's algorithm, using a combination of all the deemed prescriptive assumptions, will also have a unique Item Code prescribed. Item Codes are alpha-numeric codes that identify a specific prescriptive measure, market, implementation method and/or specification. For example 'BES-XTR-F' is an 'LED Exterior Fixtures, 2,001-5,000 lumens' and 'EPT3FCW' is a 'Residential Efficient Products Front Loading Clothes Washer (CEE Tier 3)'. Many characterizations do not currently display Item codes.

1.7 Lifetimes

The measure life quantifies the number of years (or hours) that the new high efficiency equipment is expected to function and provide the savings characterized. It is often based on the rated engineering life of the equipment, but is sometimes adjusted based on the expected *Persistence* of the savings. Persistence represents the fraction of gross measure savings obtained over the measure life. For measures where equipment tends to be removed, made inoperative, overridden or poorly maintained before the end of its rated life (e.g., controls or economizers), applying a persistence factor to adjust the measure life may be necessary. Persistence factors are applied directly to the engineering life to determine an adjusted measure life within the TRM characterization.

For early replacement/retrofit measures where a mid-life adjustment is prescribed, the expected remaining life of the existing unit will also be provided.

1.8 Measure Cost

The measure cost represents the difference in cost between the baseline condition and the efficient measure.

For a Market Opportunity baseline, the measure cost will represent an incremental cost, or the difference between the purchase and installation of the baseline equipment and the purchase and installation of the efficient equipment. Installation costs only need to be included where there is a difference between baseline and efficient installation costs.

For an Early Replacement or Retrofit measure, the measure cost is the full cost of purchase and installation, including any cost of removing and disposing of the existing equipment. The TRM will also provide the estimated purchase and installation cost of the hypothetical deferred baseline (i.e. the replacement of existing equipment that would have occurred had the efficient measure not already replaced it) and the timing of that deferred replacement cost consistent with the timing of the mid-life adjustment.

For an Early Retirement measure, the measure cost is the full cost of collection and disposal of the existing equipment.

1.9 Operation and Maintenance Cost Adjustments

For any measure where there is forecast to be a difference in the operation and maintenance (O&M) costs (including replacement of component parts such as lamps) between the baseline and the efficient case, these costs are described within the characterization. The costs and lives for up to two components each for the baseline and efficient case can be provided.

For a select number of measures, a regular O&M cost may change significantly over the life of a measure (e.g. the cost of replacement baseline bulbs before and after the impact of EISA legislation). In these cases, an equivalent annualized payment may be calculated that results in the same net present value as the actual stream of costs over the measure life.

1.10 Reference Tables

Many measures include one or more reference tables. These tables often document multiple inputs for characterizations with a large number of specific technology types (e.g. LED light fixtures) and/or the savings outputs for each unique set of deemed variables with the specified measure or item code.

1.11 Footnotes & Citations

The final section of the characterization contains footnotes which provide additional context or explanation and/or referenced citations for the assumptions provided, all of which are attached in the Reference Documents Section.

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[1] From document titled Vermont Public Service Board Order: EEU AVOIDED COSTS FOR 2016-2017 TIME PERIOD (EEU-2015-04 Order Attachment.pdf)

General Concepts and Assumptions

1.1 Reporting Category and Track Definitions

The current Efficiency Vermont Reporting Categories are presented below. These are specified with a four digit MAS90Job number:

MAS90Job	Description
6012	Business Retrofit
6013	C & I Equipment Replacement
6014	C & I New Construction
6015	Customer Credit
6017	Low Income Multi Family Retrofit
6018	Low Income Multi Family New Construction
6019	Market Rate Multi Family New Construction
6020	Market Rate Multi Family Retrofit
6032	Energy Efficient Products
6034	Low Income Single Family Homes
6036	Existing Homes
6038	Residential New Construction Single Family Homes
6041	Low Income Single Family New Construction

Within each reporting category are subcategories or Tracks which provide additional context of the project type. A list of Tracks used within the TRM can be found here.

1.2 Measure Calculation Types

There are five distinct measure calculation types described below, each with key differences in the determination of baseline.

Program	**Definition**
Market Opportunity: Time of Sale	Definition: A program in which the customer is incentivized to purchase or install higher efficiency equipment than they would have done if the program had not existed. Baseline Case = New base level equipment, often corresponding to a federal standard or at a level representing standard industry practice. Efficient Case = New, high efficiency equipment meeting a program specified level.

Program	Definition
Market Opportunity: New Construction	Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices. Baseline = New base level equipment at the efficiency level defined in the applicable Building Energy code, federal standard level or standard practice as derived by baseline studies. Efficient Case = The program's prescribed level of building specification.
Early Replacement	Definition: A program that replaces existing equipment before the end of its expected life. To qualify as early replacement, there needs to have been prior contact with the customer replacing functioning equipment – e.g. during on site audit or through prior phone/email contacts, and evidence must be provided that the unit is being replaced to achieve energy savings. Baseline = Dual; for the expected remaining useful life of the existing equipment the baseline is the efficiency of the existing equipment and then shifts to represent new baseline equipment. Efficient Case = New, high efficiency equipment meeting a program specified level.
Retrofit	Definition: A program that upgrades or enhances existing equipment. Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life. Efficient Case = Either new, high efficiency equipment or modifications of existing equipment to make it operate more efficiently.
Early Retirement	Definition: A program that retires duplicative equipment before its expected life is over. Baseline = The existing equipment, which is retired and not replaced. Efficient Case = Since the unit is retired, the efficient case consumption will be zero.

1.3 Program Delivery / Implementation Type Definitions

Presented below are descriptions of common methodologies that are used by programs to implement measures, delivering the energy saving technology(s) or practice(s) to their customers:

- Upstream: Providing incentives to manufacturers to lower the cost to the consumer of an efficient option or to invest in R&D or production of more efficient options at the start of a supply channel or to pass along the discount to distributors or retailers to decrease their costs and increase adoption and stocking.
- Midstream: Providing incentives to distributors or retailers to encourage the stocking and marketing of the efficient options and/or lower the cost to the consumer.

- Downstream: Providing incentives directly to the end user or consumer through coupons or rebates.
- Direct Install: A program where measures are installed during a site visit by a staff member or contractor.
- Free product: Product is provided to customers free of charge. This could be during a promotional event, left with customers after a site visit or through the mail.
- Efficiency Kits: A selection of low cost energy saving products are provided to customers for free or a low charge. Often kits are required to be requested to increase likelihood of installation.
- Home Energy Reports: Electricity bill inserts that provide information on a residences relative consumption compared to similar homes in the local area to encourage behavioral change and/or efficient measure purchases.

1.4 Interactive effects

In some characterizations, the savings algorithm(s) include factors to estimate the impacts of interactions of the measures with other end uses, for example, cooling and heating effects from interior lighting waste heat. The TRM does not, however, provide a methodology for accounting for interactions between measures installed concurrently.

In custom projects, Efficiency Vermont Energy Consultants perform site-specific customized calculations to account for interactions between measures (e.g., individual savings from installation of window film and replacement of a chiller are not additive because the first measure reduces the cooling load met by the second measure). If a project includes both prescriptive and custom measures, the prescriptive measures will be calculated in the normal manner and assumed to be installed prior to determining the impacts of the custom measures. To determine interacting custom measure savings, Energy Consultants calculate measure impacts in descending order of measure life (i.e., starting with the longest lived measure), assuming each prior measure is installed before calculation of the savings from the next.

1.5 Heating and Cooling Degree-Day Data

Where a characterization's variable assumptions are sensitive to outdoor temperatures, heating and cooling degree days (HCDDs) are often used to calculate site or region specific assumptions. HCDDs are calculated using TMY3 data from the Department of Energy National Oceanic and Atmospheric Administration (NOAA).

1.6 Inflation and Discount Rates

The Vermont screening tool calculates the *Net Present Value (NPV)* of an efficiency measure by comparing the initial measure cost and any future cost impacts with the present value of the energy savings over the lifetime of the measure. The following financial assumptions are used in the calculation of present value:

1.6.1 Real Discount Rate

The value of all future costs or savings are discounted to the *Program Year* using the Real Discount Rate (RDR) of 3.0%. This rate is currently affirmed in a 2015 Public Service Board ruling EEU-2015-04 "Order RE: EEU Avoided Costs for 2016-2017 Time Period".

1.6.2 Future Inflation Rate

The projected future inflation rate, used for adjusting measure costs, Operation and Maintenance costs, and deferred baseline replacement costs from the Program Year to the *Base Year* (defined as the first year of the current three year performance period). Current value is 2.0% based upon rates used in AESC 2015 Update: "10 year treasury note - Composite of CBO for 2017 thru 2026 and AEO 2016 for 2017 thru 2031".

1.6.3 Inflation Rate to Base Year

This is only used to adjust future avoided costs to the Base Year. It is based on the escalation rates used to determine the Avoided costs from the 2015 Association of Energy Service Companies (AESC) report and is currently 1.51%.

1.7 Stipulated Database Adjustments

1.7.1 RES / C&I Split for EP Retail Lighting

For upstream lighting programs delivered through Efficient Products, a specified percentage of purchases are assumed to be Residential and the remainder are assumed to be Commercial, with the relevant characterization assumptions applied to each portion. The current split is set at 89.5% Residential and 10.5% Commercial, as determined through a TAG agreement.

1.7.2 Upstream/Midstream Reconciliation

To avoid double counting of savings where measures are supported both Upstream (incentive provided to suppliers of equipment) and by a Midstream (retailers) or downstream (end-user) incentives, reconciliation procedures are in place to deduct any duplication of savings. These procedures are documented in the Efficiency Vermont Business Process Manual section of the Vine here.

Glossary of Terms

Active Date: The date from which a particular measure characterization is active and the assumptions documented are applied to new installations.

Avoided Costs: The forecasted marginal cost of generation of electric or fossil energy that an energy efficiency measure will save over its lifetime.

Base Year: The first year of the current three year Efficiency Vermont performance period. The value of all costs and savings are discounted to represent this base year's dollars.

Characterizations: Documentation of all the necessary cost-effectiveness screening assumptions for a particular measure or group of similar measures.

Coincidence Factors: Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis. Coincidence factors are provided for summer and winter peak periods.

Custom: A project or measure that requires multiple site specific inputs to complex modeling analyses, or requires pre and post metering to quantify the savings associated with it.

Environmental Externalities: The prescribing of an economic value to the environmental impact of the production (or saving) of energy.

Expected Remaining Life: The assumed remaining life of existing equipment that is being replaced for efficiency reasons prior to the end of its natural life.

Forward Capacity Market (FCM): A market based auction where bidders commit to the supply of (or savings of) future capacity in exchange for a market-priced payment.

Freeridership Factor: The fraction of gross program savings that would have occurred without the programs involvement.

Gross Savings: The estimated impact of an efficiency measure at the customer's meter(s). When multiplied by the customer's energy rates the impact on their energy bills is determined.

Item Code: An alpha-numeric codes, up to 16 characters in length, which identifies a specific prescriptive measure, market, implementation method and/or specification.

Line Loss Factors (LLF): The marginal electricity losses from the generator to the customer – expressed as a percent of meter-level savings. The Energy Line Loss Factors vary by period. The Peak Line Loss Factors reflect losses at the time of system peak, and are shown for the two seasons of the year (Summer and Winter). Line loss factors are the same for all measures.

Low Income Adder: Adjustment to account for the greater benefits resulting from energy savings in low-income sectors because the energy bill-to-income ratio is higher relative to other sectors and because non-energy benefits for comfort, health, and safety appear to be greater in that sector as well.

Measure Code: An eight-character alpha-numeric code used to identify a general measure technology and sharing the same Net to Gross Factors (Freerider and Spillover rates) within each program Track.

Net Present Value (NPV): The delta between the value of all costs and savings over the lifetime of an efficiency measure in the base year dollars.

Net Savings: The estimated impact of an efficiency measure at generation that can be attributed to the efficiency program. Calculated by incorporating the line loss factors and freeridership and spillover rates.

Non-Energy Benefit/Impacts (NEB/NEI): Additional outcomes of energy efficiency activities relating to participant, utility or societal impacts such as comfort, health, durability, productivity, property values etc. Note that Operation and Maintenance and water impacts are calculated separately and not included in any NEB adder.

Persistence: Adjustments used when appropriate to reduce lifetime savings in recognition that the measure may not provide the calculated annual savings for the entire rated engineering life of the unit.

Prescriptive: An efficiency measure that is considered appropriate to assume consistent prescribed savings for each specified application, rather than perform a custom calculation for each installation.

Program Year: The year in which an efficiency measure was reported. Efficiency Vermont program years run on a calendar year basis.

Reliability Review: An annual review process for characterizations that have not had a recent update to ensure ongoing validity, consistency and to update with new evaluation results.

Retroactive: Application of a change to an existing characterization to measures already installed and claimed in a program year.

Societal Cost Test (SCT): The principal cost effectiveness test utilized by Efficiency Vermont to evaluate the value of an efficiency measure. The net benefit to society of the activities is based upon lifetime benefits (i.e. the societal avoided costs of energy savings, including externalities (environmental benefits) and other non-energy benefits over the life of a measure) minus lifetime costs (including measure cost, O&M costs (or benefits), risk discount (to account for risks associated with investments in supply-side resources that are avoided by investing in demand side management), and avoided replacement costs).

Spillover Factor: Savings attributable to the program, but generated by customers not directly participating.

Total Resource Benefits: The total present value of the electric energy savings (or increase), electric coincident peak demand reduction (or increase), fuel savings (or increase), and water use savings (or increase) over the lifetime of the measure. Note that TRB is *not* affected by any of the following: environmental externalities, non-energy benefits and low income adders, operations and maintenance costs, measure costs, or incentives.

Track: Classification and division of Reporting Categories into subgroups of similar implementation methods.

Ultra Efficient LCD Monitors

Measure Number: IV-G-2 b
Portfolio: 89
Status: Active
Effective Date: 2016/1/1
End Date: 2021/12/31
Program: Efficient Products Program
End Use: Electronics

Update Summary

Update to ENERGY STAR Version 6 specifications.

Referenced Documents

- ENERGY STAR V6 LCD Analysis_2015_FINAL
- ECOVA_Displays Program Potential Energy Savings Analysis 8-14-14
- Michigan Electric and Natural Gas Energy Efficiency Potential Study, 2013

Description

With rapid advancements in LCD (Liquid Crystal Display) technology, LCD monitors are quickly replacing older CRT technologies in both residential and commercial applications. This program will provide an incentive with the purchase of a LCD monitor that meets or exceeds the Energy Star Version 6.0 specification by 10%, 15%, 20%, 30%, or 40% in place of one of a monitor meeting and not exceeding Energy Star Version 6.0. The monitors will be broken out into bin sizes because larger size screens consume larger amounts of energy.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

Demand savings are a weighted representation of monitors sales based on retail partners and manufacturer data reported to Ecova. This algorithm is identical for Residential and Commercial applications. Additionally, the savings are based on active mode values for both the baseline and energy efficient monitors[1].

$\Delta kW_{LCD\ Monitor}$ = WattsBASE - WattsEE / 1000

Symbol Table

Electric Energy Savings

Average Energy Savings over all hours based on efficiency savings during active, standby and idle operational modes.[697]

$\Delta kWh = (W_{BaseActive} - W_{ESActive}) / 1000 \times HOURS_{Active}$

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
$HOURS_{Active}$	=	average active hours of use of the monitor per year

Sector	Active (hr/yr)	Sleep (hr/yr)	Off (hr/yr)
Commercial[2]	2,474	4,093	2,193
Residential[3]	1,533	4,453	2,811

$W_{BaseActive}$	=	power use (in Watts) of baseline monitor while in on mode (i.e. active mode turned on and operating)
$W_{ESActive}$	=	power use (in Watts) of efficient monitor in active mode (i.e. active mode turned on and operating)
WattsBASE	=	Baseline connected Watts as a weighted average of Energy Star 6.0 LCD monitors
WattsEE	=	connected watts of high efficiency LCD monitors exceeding Energy Star 6.0 specifications

The following ΔkW and ΔkWh are per monitor.

Commercial (ΔkW)	Efficiency Level			
	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%	ESv6 + 30%
17≤d<23	0.004	0.005	0.006	0.008
23≤d<25	0.006	0.006	0.006	0.009
25≤d<61	0.009	0.009	0.009	0.018

Residential (ΔkW)	Efficiency Level		
	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%
17≤d<23	0.004	0.004	0.004
23≤d<25	0.004	0.006	0.006
25≤d<61	0.005	0.006	0.008

Commercial (ΔkWh)	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%	ESv6 + 30%
17≤d<23	7.4	10.6	10.4	15.7
23≤d<25	14.3	14.5	14.8	21.7
25≤d<61	21.4	21.4	21.4	45.6

Residential (ΔkWh)	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%
17≤d<23	7.3	7.6	6.9
23≤d<25	7.2	9.7	9.9
25≤d<61	8.4	10.9	13.7

Baseline Efficiencies

Baseline is a monitor meeting the minimum and not exceeding the Energy Star 6.0 criteria.

High Efficiency

High efficiency is an LCD Monitor exceeding the Energy Star 6.0 requirements by 10%, 15%, 20%, or 30%.[4]

Operating Hours

Operating hours vary according to usage patterns for both residential and commercial LCD monitors.

Load Shapes

Assumed load profile from 80 Plus computer program < *Internal Power Supply Load Profile.xls*>

Freeridership factor from *Work Paper: High Efficiency LCD Computer Monitor Program For the Mass Market Channel, p. 3*

74a Internal Power Supply, Commercial Desktop
75a Internal Power Supply, Residential Desktop

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
74	Internal Power Supply, Commercial Desktop	Active	39.2%	27.5%	19.6%	13.7%	50.0%	80.0%
75	Internal Power Supply, Residential Desktop	Active	33.8%	32.9%	16.9%	16.4%	52.2%	40.5%

Net Savings Factors

Net to Gross values below.[5]

Measures

EQPMONTR	Efficient Computer Monitor

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPMONTR	0.70	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Measure life is based on an estimated monitor life of 4 years. [6]

Measure Cost

The incremental cost for the Ultra Efficient LCD Monitor is $2.60[7]

O&M Cost Adjustments

$0

Fossil Fuel Description

Reference Tables

Energy Star 6.0 Display Maximum On Mode Power Table, P_{ON_MAX}

Screen Size	Displays with Dp ≤20,000 pixels/in^2	Displays with Dp > 20,000 pixels/in^2
Computer Monitors, Signage Displays, and Digital Picture Frames		
d<12.0	(6.0xr)+(0.05xA)+3.0	(6.0xr1)+(3.0xr2)+(0.05xA)+3.0
12.0≤d<17.0	(6.0xr)+(0.01xA)+5.5	(6.0xr1)+(3.0xr2)+(0.01xA)+5.5
17.0≤d<23.0	(6.0xr)+(0.025xA)+3.7	(6.0xr1)+(3.0xr2)+(0.025xA)+3.7
23.0≤d<25.0	(6.0xr)+(0.06xA)-4.0	(6.0xr1)+(3.0xr2)+(0.06xA)-4.0
25.0≤d ≤61.0	(6.0xr)+(0.1xA)-14.5	(6.0xr1)+(3.0xr2)+(0.1xA)-14.5
Signage Displays 30 Inches and Over		
30.0≤d≤61.0	(0.27xA)+8.0	(0.27xA)+8.0

Ultra Efficient LCD Monitor Power Requirements Table

Category	Energy Star 6.0
Standby (Off Mode)	≤ .5 W
Sleep Mode	≤ .5 W
Active State < 27 inches ≥ 27 inches	 0.30*P_{ON_MAX} 0.75*P_{ON_MAX}

Incentive Level

Footnotes

[1] Ecova, Displays Program Potential Energy Savings Analysis, 2014. ECOVA_Displays Program Potential Energy Savings Analysis 8-14-14.docx

[2] Page 137, Table 5-20. Navigant Consulting, Inc. (2009). *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances.* Prepared for U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program.

[3] Page 55, Table 3-34. Urban, Bryan, Verena Tiefenbeck, and Kurt Roth (2014). *Energy Consumption of Consumer Electronics in U.S. Homes in 2013.* Prepared for the Consumer Electronics Association by Fraunhofer Center for Sustainable Energy Systems.

[4] *ENERGY STAR Program Requirements for Displays (Version 6.0)*

[5] *Work Paper: High Efficiency LCD Computer Monitor Program For the Mass Market Channel, p. 3*

[6] Michigan Electric and Natural Gas Energy Efficiency Potential Study, 2013, Page 298: http://www.dleg.state.mi.us/mpsc/electric/workgroups/mi_ee_potential_studyw_appendices.pdf

[7] Page 52, Electronic Displays, Codes and Standards Enhancement (CASE) Initiative for PY 2013: Title 20 Standards Development. March 8, 2013.

Controlled Power Strip

Measure Number: IV-G-4 c
Portfolio: EVT TRM Portfolio 2018-03
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Electronics

Update Summary

Update to add assumptions for market opportunity and for free giveaways to customers who request power strips.

Referenced Documents

- Loadshape_smart_revB
- Lockeed Martin Energy Solutions nyserda_powerstrip_report
- NYSERDA_Advanced Power Strips
- Report_NEEP-APS-Deemed-Savings-Report-4-30-12
- CalPlug_Tier2_APS_Evaluation
- UVM Dorm APS Study
- Cadmus_Process Evaluation Report PPL Electric Program Year 5_Nov 2014
- Cadmus_EmPOWER_EY4 Res Retro Impact Report_FINAL_June 2014
- EVT_Controlled Power Strip Analysis_Feb 2018

Description

This measure describes savings associated with Tier I Advanced Power Strips. These multi-plug power strips have the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced.

This measure applies to the following implementation methods:

- Direct installation of power strips in residential buildings or in college dorms
- Retail sales
- Free giveways to customers who request power strips

Algorithms

Electric Demand Savings

$\Delta kW_{DI\_Entertainment\ Center}$	$= \Delta kWh_{DI\_Entertainment\ Center} / Hours_{Residential}$
ΔkW_{DI_Office}	$= \Delta kWh_{DI\_Office} / Hours_{Residential}$
$\Delta kW_{DI\_College}$	$= \Delta kWh_{DI\_College} / Hours_{College}$
ΔkW_{MOP}	$= \Delta kWh_{MOP} / Hours_{Residential}$
$\Delta kW_{Free\ Giveaway}$	$= \Delta kWh_{Free\ Giveaway} / Hours_{Residential}$

Symbol Table

Electric Energy Savings

$\Delta kWh_{DI\_Entertainment\ Center}$	$= SaveElec_{Entertainment\ Center} \times ISR$
ΔkWh_{DI_Office}	$= SaveElec_{Office} \times ISR$
$\Delta kWh_{DI\_College}$	$= SaveElec_{College} \times ISR$
ΔkWh_{MOP}	$= ((SaveElec_{Entertainment\ Center} \times \%Entertainment\ Center) + (SaveElec_{Office} \times \%Office)) \times ISR$
$\Delta kWh_{Free\ Giveaway}$	$= ((SaveElec_{Entertainment\ Center} \times \%Entertainment\ Center) + (SaveElec_{Office} \times \%Office)) \times ISR$

Where:

%Entertainment Center	=	Relative penetration of use with home entertainment systems = 59%[3]
%Office	=	Relative penetration of use in home offices = 41%[3]
$\Delta kW_{DI\_College}$	=	Gross customer connected load kW savings for direct installation of power strips in college dorms (kW) See Reference Tables section for deemed savings values
$\Delta kW_{DI\_Entertainment\ Center}$	=	Gross customer connected load kW savings for direct installation of power strips in entertainment centers in residential buildings (kW) See Reference Tables section for deemed savings values
ΔkW_{DI_Office}	=	Gross customer connected load kW savings for direct installation of power strips in home offices (kW) See Reference Tables section for deemed savings values
$\Delta kW_{Free\ Giveaway}$	=	Gross customer connected load kW savings for free giveaways (kW) See Reference Tables section for deemed savings values
ΔkW_{MOP}	=	Gross customer connected load kW savings for market opportunity (kW) See Reference Tables section for deemed savings values
$\Delta kWh_{DI\_College}$	=	Gross customer annual kWh savings for direct installation of power strips in college dorms (kWh) See Reference Tables section for deemed savings values
$\Delta kWh_{DI\_Entertainment\ Center}$	=	Gross customer annual kWh savings for direct installation of power strips in entertainment centers in residential buildings (kWh) See Reference Tables section for deemed savings values
ΔkWh_{DI_Office}	=	Gross customer annual kWh savings for direct installation of power strips in entertainment centers in home offices (kWh) See Reference Tables section for deemed savings values
$\Delta kWh_{Free\ Giveaway}$	=	Gross customer annual kWh savings for free giveaways (kWh) See Reference Tables section for deemed savings values
ΔkWh_{MOP}	=	Gross customer annual kWh savings for market opportunity (kWh)

See Reference Tables section for deemed savings values

$Hours_{College}$	=	Average hours of use per year in a college in efficient (controlled off) mode = 4,953[1]
$Hours_{Residential}$	=	Average hours of use per year in a residential application in efficient (controlled off) mode = 8,048[2]
ISR	=	In service rate, or the percentage of units rebated that are actually installed = 100% for direct install and market opportunity and 63% for free giveaways[4]
$SaveElec_{College}$	=	Annual electric energy savings (kWh) for college dorm use = 54.8[5]
$SaveElec_{Entertainment\ Center}$	=	Annual electric energy savings (kWh) for entertainment center use = 75.1[6]
$SaveElec_{Office}$	=	Annual electric energy savings (kWh)for office use = 31.0[6]

Baseline Efficiencies

The assumed baseline is a standard power strip that does not control any of the connected loads.

High Efficiency

The efficient case is the use of an advanced power strip.

Load Shapes

See Loadshape_smart_revB.xls

96a Standby Losses - Entertainment Center
97a Standby Losses - Home Office

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
96	Standby Losses - Entertainment Center	Active	32.0%	35.0%	16.0%	17.0%	72.5%	90.0%
97	Standby Losses - Home Office	Active	29.0%	38.0%	14.0%	19.0%	25.0%	76.3%

Net Savings Factors

Measures

EQPPWRHO	Residential Office Controlled Power Strip
EQPPWREC	Residential Entertainment Controlled Power Strip
EQPPWCEC	College Entertainment Controlled Power Strip

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPPWRHO	1.00	1.00
Efficient Products - Residential	6032EPEP	EQPPWREC	1.00	1.00
LISF Retrofit	6034LISF	EQPPWRHO	1.00	1.00
LISF Retrofit	6034LISF	EQPPWREC	1.00	1.00
Res Retrofit	6036RETR	EQPPWRHO	1.00	1.00
Res Retrofit	6036RETR	EQPPWREC	1.00	1.00
Efficient Products - Residential	6032EPEP	EQPPWCEC	1.00	1.00
LISF Retrofit	6034LISF	EQPPWCEC	1.00	1.00
Res Retrofit	6036RETR	EQPPWCEC	1.00	1.00

Persistence

The persistence factor is assumed to be 1.

Lifetimes

The expected lifetime of the measure is 5 years[7].

Measure Cost

The installation cost of the measure is $21.48[8]

Measure costs are presented below, depending on program type.

Program Type	Measure Cost
Direct Install	$23.75[9]
MOP	$21.48[8]
Free Giveaway	$13.75[10]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Reference Tables

Savings are presented below, depending on program type.[5]

Program Type	ΔkW	ΔkWh
Direct Install: Entertainment Center	0.00933	75.1
Direct Install: Office	0.00385	31.0
Direct Install: College Dorm	0.01106	54.8
MOP	0.00708	57.0
Free Giveaway	0.00446	35.9

Footnotes

[1] Refer to APS in Dorms tab of analysis document: EVT_Controlled Power Strip_Analysis_Feb 2018.xlsx. Annual hours for college applications are calculated assuming a 32 week school year and results in 4,953 hours a year.

[2] Derived from CalPlug Tier 2 APS Evaluation Study Retrieved from: http://embertec.com/assets/pdf/CalPlug_Tier2_APS_Evaluation.pdf. Advanced Power Strips are assumed to be plugged in at all times. Annual hours when the equipment is turned off are 7,340. The equipment is estimated to be in standby mode 1.94 hours/day or 708 hours/year. Savings are achieved during periods when equipment is off or in standby mode. Thus, the hours of operation used to determine demand savings are 7,340 + 708 = 8,048. No savings are achieved during the remaining 712 hours per year when equipment is in use.

[3] Relative weightings of home office and entertainment systems is based on Cadmus Group & Navigant, "EmPower Maryland Final Evaluation Report – Evaluation Year 4; Residential Retrofit Programs," June 23, 2014, p. 91.

[4] Advanced power strip ISR is average of ISRs from Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five," November 13, 2014, p. 147.

[5] Analysis of energy savings from VEIC study at the University of Vermont. APS in Dorms: A New Application for Savings?, Vermont Energy Investment Corporation, 2014. Refer to analysis on APS in Dorms tab on EVT_Controlled Power Strip_Analysis_Feb 2018.xlsx.

[6] Advanced Power Strips Deemed Savings Methodology, Northeast Energy Efficiency Partnerships (NEEP), January 2012. Refer to Report_NEEP-APS-Deemed-Savings-Report-4-30-12.pdf.

[7] 10-year estimate: Lockheed Martin, Inc., Energy Solutions, Advanced Power Strip Research Report Final Report, Prepared for the New York State Energy Research and Development Authority (NYSERDA), 2011. As persistence has not been studied for this measure, 5 years is being used as a conservative estimate.

[8] Average of 5-plug and 7-plug incremental cost differences between a power strip and an advanced power strip, NYSERDA Advanced Power Strips Report, Page 4.

[9] Full installation cost for direct install based on actual program cost of $13.75 for an advanced power strip and labor estimated at 1/2 hour at $20/hour.

[10] Cost of an advanced power strip for free giveaways from actual program data.

ENERGY STAR Computers

Measure Number:	IV-G-5 b
Portfolio:	EVT TRM Portfolio 2019-07
Status:	Active
Effective Date:	2019/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	Electronics

Update Summary

Updated desktop computer to incorporate ENERGY STAR v7.0 specifications. Added notebook and thin clients as device options in addition to the existing desktop computer offerings.

Changed the name of the measure from Desktop Computers to ENERGY STAR Computers. Created a new measure code and included new net savings factors.

Referenced Documents

- Research Into Action_ NEEA 80 PLUS Market Progress Evaluation_Nov 2013
- CA IOUs_Computers CASE Initiative PY2013_Aug 2013
- California IOUs_Supplemental CASE Technical Report Computers_Jan 2014
- 80 PLUS Desktop Savings_25Aug2014_Revised ESv7
- ENERGY_STAR_Certified_Computers_v7_Dec 2018
- ENERGY STAR Office Equipment Calculator
- EVT_Computers_Analysis_May 2019

Description

This measure is for ENERGY STAR rated desktop computers and select portable computers such as notebooks and thin clients. Energy savings for these devices are characcterized for both commercial and residential applications. The applicable ENERGY STAR specification is version 7.0, which was made effective on November 16, 2018.

In addition to notebook and thin clients, this measure includes desktop computers with Energy Star Version 7.0 rating, ES 7.0 +20%, ES 7.0 with 80 PLUS Platinum PSUs, and ES 7.0 with 80 PLUS Titanium PSUs.

Program Type

Market Opportunity

Program Delivery / Implementation Type

Downstream

Baseline Efficiencies

The baseline measure is a desktop, notebook, or thin client with no Energy Star rating. The baseline wattage draw for each device at the four primary modes of operation are detailed in the table below. The total energy consumption is based on the algorithm and primary mode of operation loadshape, which is shown in more detail further on in the characterization.

Baseline Operating Parameters[1]

Measure Watt Draw in Mode (Watts)	Off	Sleep	Long Idle	Short Idle	Residential Total Energy Consumption (kWh)	Commercial Total Energy Consumption (kWh)
Desktop Baseline	0.88	2.10	26.50	27.90	83.28	124.75
Notebook Baseline	0.53	1.20	5.75	11.03	11.14	38.88
Thin Client Baseline	1.12	8.71	8.71	10.55	25.20	52.00

Efficient Equipment

The efficient measure is a desktop, notebook, or thin client with an ENERGY STAR v7.0 rating. Additional derivations of desktop computers are included, depending on their increased efficiencies over ENERGY STAR v7.0 rating (ES 7.0 +20%) or a pairing with a high efficiency 80 PLUS PSU (ES 7.0 with 80 PLUS Platinum PSUs or ES 7.0 with 80 PLUS Titanium PSUs).

Efficient Operating Parameters

Measure Watt Draw in Mode (Watts)	Off	Sleep	Long Idle	Short Idle
ES 7.0 Desktops[2]	0.69	1.49	16.70	18.15
ES 7.0 +20% Desktops[3]	0.70	1.46	16.30	17.77
ES 7.0 Desktops w/ 80 PLUS Platinum PSUs[4]	0.50	1.50	15.53	16.88
ES 7.0 Desktops w/ 80 PLUS Titanium PSUs[5]	0.50	1.50	15.18	16.50
ES 7.0 Notebook[6]	0.31	0.70	3.33	6.39
ES 7.0 Thin Client[6]	0.71	5.53	5.53	6.70

Algorithms

Electric Demand Savings

$\Delta kW = (Watts_{Base,Long} - Watts_{Eff,Long})/1000$

Symbol Table

Water Savings

N/A

Electric Energy Savings

$\Delta kWh = 8760/1000 \times (((Watts_{Base,Off} \times \%Time_{Off}) + (Watts_{Base,Sleep} \times \%Time_{Sleep}) + (Watts_{Base,Long} \times \%Time_{Long}) + (Watts_{Base,Short} \times \%Time_{Short})) - ((Watts_{Eff,Off} \times \%Time_{Off}) + (Watts_{Eff,Sleep} \times \%Time_{Sleep}) + (Watts_{Eff,Long} \times \%Time_{Long}) + (Watts_{Eff,Short} \times \%Time_{Short})))$

Symbol Table

Fossil Fuel Savings

N/A

Where:

$\%Time_{Long}$	=	typical percent time in long idle mode
$\%Time_{Off}$	=	typical percent of time a desktop, integrated desktop or notebook is in off mode during the year
$\%Time_{Short}$	=	typical percent time in short idle mode
$\%Time_{Sleep}$	=	typical percent time in sleep mode
ΔkW	=	gross customer connected load kW savings for the measure (kW)
ΔkWh	=	gross customer annual kWh savings for the measure (kWh)[7]
$Watts_{Eff,Off}$	=	power in off mode
$Watts_{Base,Long}$	=	power in long idle mode

$Watts_{Base,Sleep}$	=	power in sleep mode
$Watts_{Eff,Long}$	=	power in long idle mode
$Watts_{Eff,Short}$	=	power in short idle mode
$Watts_{Eff,Sleep}$	=	power in sleep mode
$Watts_{Base,Long}$	=	power in long idle mode
$Watts_{Base,Off}$	=	power in off mode
$Watts_{Base,Short}$	=	power in short idle mode
$Watts_{Eff,Long}$	=	power in long idle mode

Deemed Energy and Demand Savings

Measure	Item Code		Energy Savings (kWh)		Demand Savings (kW)	
	Residential	Commercial	Residential	Commercial	Residential	Commercial
ES 7.0 Desktops	EPRESPCA	EPCOMPCA	29.4	43.8	0.0098	0.0098
ES 7.0 +20% Desktops	EPRESPCB	EPCOMPCB	30.6	45.5	0.0102	0.0102
ES 7.0 Desktops w/ 80 PLUS Platinum PSUs	EPRESPCC	EPCOMPCC	33.5	50.0	0.0110	0.0110
ES 7.0 Desktops w/ 80 PLUS Titanium PSUs	EPRESPCD	EPCOMPCD	34.5	51.6	0.0113	0.0113
ES 7.0 Notebook	EPRESNOTE	EPCOMNOTE	4.7	16.4	0.0024	0.0024
ES 7.0 Thin Client	EPRESTHIN	EPCOMTHIN	9.2	19.0	0.0032	0.0032

Operating Hours

Measure Annual Mode Time (%)	Off	Sleep	Long Idle	Short Idle
Duty Cycle - Commercial Desktop and Thin Client[8]	45%	5%	15%	35%
Duty Cycle - Commercial Notebook[8]	25%	35%	10%	30%
Duty Cycle - Residential Desktop[9]	44%	24%	22%	10%
Duty Cycle - Residential Notebook and Thin Client[10]	78%	15%	2%	5%

Mid-Life Savings Adjustment

N/A

Load Shapes

74a Internal Power Supply, Commercial Desktop
75a Internal Power Supply, Residential Desktop

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
74	Internal Power Supply, Commercial Desktop	Active	39.2%	27.5%	19.6%	13.7%	50.0%	80.0%
75	Internal Power Supply, Residential Desktop	Active	33.8%	32.9%	16.9%	16.4%	52.2%	40.5%

Net Savings Factors

Measures

EQPESCOM Energy Star Computers

Tracks [Base Track]

6032EPEP [is base track] Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPESCOM	0.60	1.00

Lifetimes

The expected lifetime of the measure is 4 years.[11]

Measure Cost

The incremental cost for a Thin Client is $1.

The incremental cost for a Notebook and 80 Plus Desktop PSU is $5.

The incremental cost for a Energy Star desktop PSU is $20.[12]

O&M Cost Adjustments

N/A

Reference Tables

Footnotes

[1] The desktop computer baseline power levels at the varying primary modes of operation (off, sleep, short idle, and long idle) are sourced from, "Computers: Technical Report – Supplemental Analysis and Test Results, Supplemental to CASE Report submitted on August 6, 2013," California Energy Commission, January 2014 (page 30, table 14). The notebook and thin client baseline wattage draws are sourced as a striaght average of non-qualifying products for Tier 1 and Tier 2, as detailed in the "Computers: Codes and Standards Enhancement (CASE) Initative for PY2013: Title 20 Standards Development, Analysis of Standards Proposal for Computers", California Energy Commission, August 2013 (page 6). As the source material detailed the total baseline energy consumption for notebooks and thin clients, in order to determine the power levels at the different modes of operation, the devices annual mode time was leveraged and the power levels backed out.

[2] Analysis of current DT I2 category desktops in the ENERGY STAR version 7.0 Qualified Products List (QPL) as accessed on 12/03/2018 (see, "ENERGY_STAR_Certified_Computers_v7.0_17Dec2018.xlsx")

[3] Analysis of current DT I2 category desktops in ENERGY STAR version 7.0 QPL, passing with > 20% margin, as accessed on 12/03/2018 (see, "ENERGY_STAR_Certified_Computers_v7.0_17Dec2018.xlsx")

[4] 80 PLUS program savings calculator, additional 7% reduction in idle power levels over ENERGY STAR version 7.0 computers with 80 PLUS Silver PSU levels. The program calculator was used to establish relative and comparable savings, and as a result, absolute idle power values do not match. For more details on the derivation of the 7% savings factor, please see, "80 PLUS Desktop Savings_25Aug2014_Revised ESv7.xlsx", 'Analysis Summary' tab

[5] 80 PLUS program savings calculator, additional 9.1% reduction in idle power levels over ENERGY STAR version 7.0 computers with 80 PLUS Silver PSU levels. The program calculator was used to establish relative and comparable savings, and as a result, absolute idle power values do not match. For more details on the derivation of the 9.1% savings factor, please see, "80 PLUS Desktop Savings_25Aug2014_Revised ESv7.xlsx", 'Analysis Summary' tab

[6] Analysis of all applicable categories for notebooks and thin clients in the ENERGY STAR version 7.0 QPL, as accessed on 02/05/2019 (see "EVT_Computers_Analysis_May 2019.xlsx")

[7] Algorithm is originally sourced from the "Energy Star Program Requirements, Product Specification for Computers, Eligibility Criteria Version 7.0", effective November 16, 2018 (page 15, Equation 4: Calculation for Workstations) and further corroborated by the ENERGY STAR Office Equipment Calculator, which is included as a reference to this measure characterization.

[8] The commercial duty cycle for devices is sourced from the ENERGY STAR Program Requirements, Product Specification for Computers, Eligibility Criteria Version 7.0, effective November 16, 2018 (page 12; tables 4-5: mode weightings)

[9] "Energy Consumption of Consumer Electronics in U.S Homes in 2013", Fraunhofer, June 2014, (page 30, table 3-13)

[10] The residential duty cycle for notebook and thin clients are sourced from the ENERGY STAR Office Equipment Calculator, Labtops. The assumptions were made that ENERGY STAR labtop operation mirrors that of notebooks and thin clients as they all fall under the portable labtop device category. Additionally, as idle time was not included, assumed a similar distribution from ENERGY STAR specifications for commercial products.

[11] "Computers: Codes and Standards Enhancement (CASE) Initative for PY2013: Title 20 Standards Development, Analysis of Standards Proposal for Computers", California Energy Commission, August 2013 (page 6)

[12] The 80 PLUS Desktop PSU and ENERGY STAR Desktop PSU incremental costs are sourced from "NEEA 80 PLUS Market Progress Evaluation Report #5", Research Into Action, November 26, 2013 (page 24). The incremental costs for the notebook and thin client are sourced from "Computers: Codes and Standards Enhancement (CASE) Initative for PY2013: Title 20 Standards Development, Analysis of Standards Proposal for Computers", California Energy Commission, August 2013 (page 41)

80 PLUS Servers

Measure Number: IV-G-6 b
Portfolio: EVT TRM Portfolio 2018-11
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Electronics

Update Summary

Updated the measure to reflect the new ENERGY STAR specification for servers, version 3.0. The measure characterization for servers leverages 80 PLUS specifications. It had Silver as the baseline and deemed savings for Gold, Platinum, and Titanium. The new ENERGY STAR specification essentially has 80 PLUS Platinum as the new minimum qualifying criteria. As a result, removed the deemed savings for Gold, seeing as it no longer meets the minimum qualifying criteria for ENERGY STAR. For added reference, I contacted 80 PLUS and asked it, with these new ENERGY STAR specifications, are they planning on making any changes to their rating system, and they responded that there were no current planned revisions.

Referenced Documents

- Internal Power Supply Load Profile
- 80 PLUS Servers Calculator_Xcel_14Aug2014
- 2015-6 - Computer Efficiency - Power Supply TAs FINAL
- ENERGY_STAR_Certified_Enterprise_Servers_20150803
- Server Power Supplies Data Points_PMO
- NREL_UMP Chapter 20
- ENERGY STAR Computer Sever Program Requirements_Version 3

Description

Commercial customer incentives for installing servers with power supplies rated at or higher than 80 PLUS Platinum [1]. At the moment, 80 PLUS Silver efficiency power supplies are most commonplace in the market and will serve as the baseline. 80 PLUS Platinum and 80 PLUS Titanium power supplies are eligible for incentive.

Baseline Efficiencies

The baseline efficiency for this measure is an 80 PLUS Silver server.

Efficient Equipment

The high efficiency for this measure is a server that is rated as an 80 PLUS Platinum or 80 PLUS Titanium.

Algorithms

Electric Demand Savings

ΔkW	$= ((\text{PSU Watt}_{Baseline} / (1000 \times \text{Server Efficiency}_{Baseline})) - (\text{PSU Watt}_{Efficient} / (1000 \times \text{Server Efficiency}_{Efficient}))) + \text{Cooling Interaction kW}$

Symbol Table

Electric Energy Savings

ΔkWh	$= ((\text{PSU Watt}_{Baseline} / (1000 \times \text{Server Efficiency}_{Baseline})) - (\text{PSU Watt}_{Efficient} / (1000 \times \text{Server Efficiency}_{Efficient}))) + \text{Cooling Interaction kWh}$

Where:

ΔkW	=	gross customer connected load kW savings for the measure
Cooling Interaction kW	=	Cooling load reduction based on tonnage[3]
Cooling Interaction kWh	=	Cooling load reduction based on cooling FLH[6]
HOURS	=	Hours of operation for the measure = 8760
$\text{PSU Watt}_{Baseline}$	=	Wattage of baseline power supply unit[4]
$\text{PSU Watt}_{Efficient}$	=	Wattage of efficient power supply unit[5]
$\text{Server Efficiency}_{Baseline}$	=	Refer to Table 1: Power Supply Efficiency
$\text{Server Efficiency}_{Efficient}$	=	Refer to Table 1: Power Supply Efficiency

Deemed Energy and Demand Savings[2]

Measure Description	Item Code	Energy Savings (kWh)	Demand Savings (kW)
Computer Server; with <400W Units with Platinum Rated Power Supply	EP80PLAT1	83	0.01
Computer Server; with 400-600W Units with Platinum Rated Power Supply	EP80PLAT2	138	0.02
Computer Server; with 600-1000W Units with Platinum Rated Power Supply	EP80PLAT3	207	0.03
Computer Server; with >1000W Units with Platinum Rated Power Supply	EP80PLAT4	386	0.05
Computer Server; with <400W Units with Titanium Rated Power Supply	EP80TITAN1	116	0.01
Computer Server; with 400-600W Units with Titanium Rated Power Supply	EP80TITAN2	193	0.02
Computer Server; with 600-1000W Units with Titanium Rated Power Supply	EP80TITAN3	290	0.04
Computer Server; with >1000W Units with Titanium Rated Power Supply	EP80TITAN4	541	0.07

Load Shapes

Desktop and Datacenter Server.[7]

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%

Net Savings Factors

Measures

EQPCMPTR Efficient Computers/Servers

Tracks [Base Track]

6032EPEP [is base track] Efficient Products - Residential

Lifetimes

Measure life[8] is based on an estimated server life of 5 years.

Measure Cost

The incremental cost for the 80 PLUS Servers are as follows:[9]

- Platinum: $40
- Titanium: $75

Reference Tables

Table 1: Power Supply Efficiency[10]

Loading	Silver (Baseline)	Platinum	Titanium
5%	75.1%	85.6%	90.6%
10%	79.0%	87.9%	92.1%
15%	82.9%	90.2%	93.5%
20%	86.8%	92.5%	94.9%
30%	88.0%	93.1%	95.3%
40%	89.2%	93.7%	95.8%
50%	90.4%	94.3%	96.2%
60%	90.1%	94.0%	95.9%
70%	89.8%	93.7%	95.6%
80%	89.5%	93.4%	95.3%
90%	89.2%	93.2%	95.1%
100%	88.9%	92.9%	94.8%

Footnotes

[1] 80 PLUS servers website: http://www.plugloadsolutions.com/80pluspowersupplies.aspx.

[2] Refer to Electric Forecast Summary tab in the document: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.xlsx

[3] Refer to the analysis file for calculation of Cooling Interaction kW: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[4] This is calculated by multiplying baseline input wattage x number of power supplies x load factor. This analysis can be found in 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[5] his is calculated by multiplying efficient input wattage x number of power supplies x load factor. This analysis can be found in 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[6] Refer to the analysis file for calculation of Cooling Interaction kWh: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[7] See < *Internal Power Supply Load Profile.xls*>

[8] NREL, *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*, Chapter 20 Data Center IT Efficiency Measures, January 2015 (Page 17.)

[9] Refer to the economic assumption and incremental costs in the analysis file: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.xls

[10] 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX supplied by Ecova on 4/14/2016

High Efficiency Pre-Rinse Spray Valve

Measure Number: CI-HWE-PRSV a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Hot Water

Update Summary

New measure

Referenced Documents

- U.S. DOE_Building America Standard DHW Schedules_May 2014
- US DOE_Energy Standards CPSV_Nov 2015
- EPA WaterSense_Commercial PRSV Notice Sunset_Oct 2018
- Cadmus_WI Focus on Energy Potential Study_ June 2017
- ENERGY STAR CKE Calculator_Oct 2016
- EVT_Pre-Rinse Spray Valve_Analysis

Description

Pre-rinse spray valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. More efficient spray valves use less water thereby reducing water consumption and hot water heating consumption. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. Pre-rinse spray valves are manually operated, and the frequency of use depends on the volume of dirty dishes washed at a facility. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

The measure replaces existing higher-flow pre-rinse sprayers used in commercial kitchens with low-flow prerinse sprayers. Installing these devices is an inexpensive and lasting approach to water conservation. These products save energy by reducing the amount of energy needed to process, move, and heat water. The annual energy savings come from replacing a standard pre-rinse sprayer head with a lowflow pre-rinse sprayer.

Program Type

Calculation Type: Time of Sale (Market Opportunity) and Retrofit

Program Delivery / Implementation Type: Midstream

Baseline Efficiencies

The baseline equipment is a less-efficient pre-rinse spray valve, with a flow rate depending on the replacement scenario.

For Time of Sale (TOS) replacement scenarios, the baseline equipment is a new pre-rinse spray valve with a flow rate meeting federal appliance standards of 1.23 gpm.[1]

For retrofit replacement scenarios, the baseline equipment is an existing pre-rinse spray valve of an assumed 1.60 gpm.[2]

Efficient Equipment

The efficienct equipment is a pre-rinse spray valve with a flow rate of 0.984 gpm or less.[3]

Algorithms

Water Savings

$$\Delta CCF = ((GPM_{Base} - GPM_{EE}) \times 60 \times Hours) / 748$$

Symbol Table

Electric Demand Savings

There are no electric demand savings for this measure.

Electric Energy Savings

$$\Delta kWh = (GPM_{Base} - GPM_{EE}) \times 60 \times Hours \times 8.33 \times (T_{out} - T_{in}) \times (1 / \eta) / 3412 \times Elec_{Water}$$

Symbol Table

Fossil Fuel Savings

$$\Delta MMBtu = (GPM_{Base} - GPM_{EE}) \times 60 \times Hours \times 8.33 \times (T_{out} - T_{in}) \times (1 / \eta) / 1000000 \times (1 - Elec_{Water})$$

Where:

ΔCCF	=	Gross customer annual water savings for the measure
ΔkWh	=	Gross customer annual kWh energy savings
$\Delta MMBtu$	=	Gross customer annual MMBtu energy savings
η	=	Efficiency of the existing hot water heater[5] = 98% for electric water heaters = 70% for natural gas- and propane-fired water heaters = 67.5% for oil-fired water heaters
1000000	=	Conversion from Btu to MMBtu
3412	=	Conversion from Btu to kWh
60	=	Minutes per hour
748	=	Constant to convert from gallons to CCF
8.33	=	Density of water
$Elec_{Water}$	=	Adjustment factor used to direct the hot water heating savings depending on fuel type = 1 for electric hot water heaters = 0 for fuel-fired hot water heaters
GPM_{Base}	=	Flow rate of the baseline pre-rinse spray valve in gallons per minute = 1.23 gpm for time of sale = 1.60 gpm for retrofit
GPM_{EE}	=	Flow rate of the installed pre-rinse spray valve in gallons per minute = 0.984 gpm
Hours	=	Annual hours of operation of the pre-rinse spray valve = 333 hours[4]
T_{in}	=	Water temperature entering the hot water heater = 51.9°F[6]
T_{out}	=	Set temperature of the hot water heater

= 121.9ºF[7]

Deemed Energy Savings

Measure Replacement Scenario	Retrofit		Time of Sale	
Hot Water Fuel Type	Annual Energy Savings	Item Code	Annual Energy Savings	Item Code
Electric (ΔkWh)	2,146	HWECPSVERET	857	HWECPSVETOS
Natural Gas (MMBtu)	10.252	HWECPSVNGRET	4.094	HWECPSVNGTOS
Propane (MMBtu)	10.252	HWECPSVPRET	4.094	HWECPSVPTOS
Oil (MMBtu)	10.632	HWECPSVORET	4.246	HWECPSVOTOS

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

HWESPRAY	Low flow Pre-Rinse Spray Valve

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	HWESPRAY	1.00	1.00

Lifetimes

The measure life is 5 years.[8]

Measure Cost

For a time of sale replacement scenario, the incremental cost is $0. For retrofit replacements, the incremental cost is $76.[8]

Reference Tables

Deemed Water Savings

Measure Replacement Scenario	ΔCCF
Time of Sale	6.571
Retrofit	16.454

Footnotes

[1] Baseline for TOS programs is calculated using the maximum flow rate for each product class, per the Federal Appliance Standards for energy conservation criteria for commercial prerinse spray valves, effective January 28, 2019 (10 CFR 431.266), weighted by estimated 2018 shipments for each product class from Table 3.6.1: U.S. DOE, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Prerinse Spray Valves," December 2015

[2] Code of Federal Regulations, Energy Conservation Standards for Commercial Prerinse Spray Valve (10 CFR 431.266), effective January 1, 2006. Assuming, in retrofit scenarios, the existing pre-rinse spray valve met the federal appliance standards from 2006, qualifying existing units as 14 years or less in age. For added context on the federal energy conservation standards, see: EPA Water Sense, "WaterSense Notice of Sunset of the Specification for Pre-Rinse Spray Valve", October 2018

[3] Prior to the federal appliance standards recent adoption of new code requirements for pre rinse spray valves in 2019, EPA WaterSense detailed efficient specifications at 20% improvement over federal criteria. Recommending a comparable 20% improvement over current federal appliance standards. (EPA Water Sense, "WaterSense Notice of Sunset of the Specification for Pre-Rinse Spray Valve", October 2018)

[4] Energy Star Certified Commercial Kitchen Equipment Calculator, 2016. Assumes 64 minutes of operation per day, 312 days per year. The number of days per year is based on restaurants being open for six out of seven days per week.

[5] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%. The efficiency of the natural gas- and propane-fired water heaters are based on the 2019 Wisconsin Focus on Energy TRM which sourced, Cadmus, "2016 Potential Study for Focus on Energy", data maintained by Cadmus and the Wisconsin Public Service Commission and based on 50 restaurant sites. For oil-fired water heaters, conservative assumption based on the efficiencies of the natural gas and propane water heaters, and how VT CBES 2005, 2011, and 2015 required typically 2 or 3% points lower for commercial oil water heaters

[6] Average value for Burlington, Montpelier, Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.

[7] Assuming a 70 degree temperature rise from the inlet temperature per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies. Corroborated by the Energy Star Certified Commercial Kitchen Equipment Calculator, 2016.

[8] Measure life and incremental costs are based on the life-cycle cost analysis as sourced from U.S. Department of Energy, "Energy Conservation Standards for Commercial Pre-Rinse Spray Valves", November 2015 (10 CFR Part 429 and 431; Docket Number EERE-2014-BT-STD-0027)

Flexible Load Management: Residential Electric Water Heater Controls

Measure Number: FLM-RES-WHC a
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Residential & Multifamily
End Use: Hot Water

Update Summary

This is version 1.0 of the characterization.

Referenced Documents

- _MA_Loadshape_RES-1-FINAL-Comprehensive-Report-2018-07-27
- WaterHeating_FlexLoadPotential

Description

Load flexibility is enabled through controls and supporting hardware that safely increase the temperature of the hot water inside the insulated water tank before the flexible resource is needed. The thermal storage of the water tank supplies hot water when needed by the customer but does not typically need to draw additional power during on peak times. The resource must be capable of being connected to an active distribution utility grid-management program such that it can be dispatched during peak times.

This measure is applicable to both electric resistance water heaters (ERWH) as well as heat pump water heaters (HPWH).

Program eligilibity requires that the system needs to have a tempering valve that is in good condition and properly set. This is also required by Vermont code.

Installation of controls is considered a retrofit activity.

Baseline Efficiencies

Baseline is an ERWH or HPWH without control equipment and therefore no grid interactivity.

Efficient Equipment

The efficient condition is defined as an ERWH or HPWH that has either had controls enabled or been retrofitted with controls and necessary supporting hardware that would enable a distribution utility to control its electric load draw. It has the ability to be grid interactive, meaning it's capabable of providing grid balancing services as determined by the distribution utility.

Algorithms

Electric Demand Savings

No electric demand savings are claimed. Data will be collected and shared over 2021-2023 to understand if and how distribution utilities are able to utilize this resource. EVT is committed to collecting the necessary data to understand any demand savings and their seasonal coincidence factors.

Flexible Load kW

As defined by PIP #125 Flexible Load Management (FLM), **Flexible Load kW** is the maximum amount of demand reduction available to be controlled for at least one hour between 4pm and 10pm on any day in any season, measured and reported in units of kW.

At best, controls could allow complete shutoff of water heaters for any given hour and therefore Flexible Load kW is estimated by considering the typical power draw of an ERWH and HPWH during the hours between 4pm and 10pm.

The RES 1 BASELINE LOAD SHAPE STUDY, Prepared for The Electric and Gas Program Administrators of Massachusetts, Navigant 2018 (see reference files) provides an hourly summary of demand, by month, for ERWHs and HPWH and is used as the basis to deem the following impacts:

Electric Water Heater Type	ItemCode	Flexible Load kW Credit (kW)[1]
Electric Resistance	FLM-RESDHW-ER	0.40931
Heat Pump	FLM-RESDHW-HP	0.17472

Electric Energy Savings

No energy savings are claimed, or necessarily expected. EVT recognizes there is a possibility that controlled HPWHs in particular may see an increase in electricity consumption, especially for those that have secondary resistance heating coils. EVT is committed to tracking and reporting kWh impacts for participants and will make appropriate revisions to claimed energy impact when more is understood.

Fossil Fuel Savings

None.

Load Shapes

This is a placeholder loadshape until data collection can inform a more appropriate choice.

8a Residential DHW conserve

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7%	29.1%	14.3%	7.9%	40.1%	20.3%

Net Savings Factors

Measures

FLMHWEHW	Flexible Load Management - Domestic Hot Water

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	FLMHWEHW	1.00	1.00

Lifetimes

A measure life of 3 years is assumed, which considers several factors:

- Water heater controls are a new and evolving technology
- Some level of attrition is possible given the behavioral component that influences impact
- Controls will be installed on existing water heaters

Measure Cost

Measure costs include the material cost of controls and the electrician labor cost to install them.

Electric Water Heater Type	ItemCode	Controller Cost[2]	Labor Cost[3]	Total Cost
Electric Resistance	FLM-RESDHW-ER	$137.5	$125	$262.5
Heat Pump	FLM-RESDHW-HP	$150	$125	$275

Footnotes

[1] See referenced document **WaterHeating_FlexLoadPotential** for derivation of deemed savings. Loadshape data from the MA Loadshape Study is used as the basis and average demand is calculated over the entire year for the time period between 4pm and 10pm.

[2] Assumes Mello controller for electric resistance water heater, which retails for $125-$150 (average of $137.5) and $150 for a Skycentrics CTA-2045 control module for heat pump water heater.

[3] Assumes a one-hour labor charge for installation of controls by an electrician.

Heat Recovery Units for Dairy Farms

Measure Number: I-K-2 b
Portfolio: EVT TRM Portfolio 2017-11
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Hot Water

Update Summary

- Due to the relatively low volume of measures prescriptively implemented, this measure was not opted for a major algorithm overhaul. As the original characterization for this measure aggregated savings and costs over a 9 year period for custom projects from 2003 to 2012, it was decided to incorporate custom projects from 2013 through 2017 to supplement these values.
- Due to a limited effect on the savings estimates, these values were not updated.
- The only revision made was to the incremental cost estimates. The updated costs are an average of 68 custom projects implemented from 2010 through 2017. Subsequent edits were made to the analysis file as well to incorporate the newer project data.

Referenced Documents

- Dairy-HRU-Analysis_v3

Description

A system used in dairy applications that uses waste heat from the compressor of a refrigerated milk cooling system to pre-heat water for either an electric or fossil fuel water heating system.

Estimated Measure Impacts

	Average Annual Savings per unit	Average number of measures per year[1]	Average Annual Savings per year
Heat Recovery Unit (Electric Savings)	6.378 MWH	11	70.16 MWH
Heat Recovery Unit (Fossil Fuel Savings)	52.46 MMBTU	14	734.4 MMBTU

Algorithms

Electric Demand Savings

ΔkW = 4.475 kW

Symbol Table

Electric Energy Savings

ΔkWh = 6,378 kWh

Symbol Table

Fossil Fuel Savings

ΔMMBTU = 52.46 MMBTU

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer average annual kWh savings for the measure
ΔMMBTU	=	gross customer average annual MMBTU savings for the measure

Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2012, see Dairy HRU Analysis_v3.xls

Baseline Efficiencies

The baseline reflects no heat recovery from the refrigerator compressor.[2]

High Efficiency

The high efficiency case is installation and use of a heat recovery unit on the refrigerator compressor.

Operating Hours

N/A.

Load Shapes

111a Farm Plate Cooler / Heat Recovery Unit

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
111	Farm Plate Cooler / Heat Recovery Unit	Active	29.0%	16.4%	31.6%	23.1%	27.0%	16.1%

Net Savings Factors

Measures

HWEHRCMP	Heat recovery, compressor

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Persistence

The persistence factor is assumed to be one.[3]

Lifetimes

10 years.

Measure Cost

Heat Recovery Unit (Electric or Fossil Fuel Savings): $4,353 [4]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default savings when electric savings is claimed for this measure. As the energy savings are associated with the water heater, fossil fuel savings occur if the water heater uses fossil fuel rather than electricity.

Footnotes

[1] Assumes that there will be ~50% more Rx measures per year than the average number of custom measures per year from 2003 through 2011, see AG HRU Analysis.xls

[2] While a heat recovery unit would be baseline for a new construction project, farmers typically re-use old equipment when extensively renovating old facilities. New construction, due to construction of new facilities, is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

[3] This equipment has no moving parts or controls and therefore rarely experiences downtime prior to failure due to corrosion at the end of service life.

[4] Value derived from Efficiency Vermont custom data 2010-2017, see Dairy HRU Analysis_v3.xls

Thermostatically Initiated Shower Restriction Valve

Measure Number:	IV-I-2 c
Portfolio:	EVT TRM Portfolio 2018-03
Status:	Active
Effective Date:	2018/1/1
End Date:	2021/12/31
Program:	Efficient Products Program
End Use:	Hot Water

Update Summary

Update to revise the implementation method for this measure to free giveaways of products that are requested by customers.

Referenced Documents

- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Cadmus_Showerhead and Faucet Aerator Meter Study_June 2013
- Navigant_energySMART Energy Savings Kits_Apr 2016
- U.S. Census Bureau_ACS Table DP04 Vermont_2015
- U.S. DOE_Building America Standard DHW Schedules_May 2014
- Sherman_Disaggregating Residential Shower Warm-Up Waste_Aug 2014
- EVT_Shower Restriction Valve_Analysis_Feb 2018_v2

Description

This measure relates to the installation of a thermostatically initiated shower restriction valve in a home. The valve prevents hot water waste during shower warm-up by closing off flow once hot water has reached the fixture. The valve is reopened manually by pulling down on a connected cord. Once flow has been cut off after the shower, the valve resets itself. This measure applies to free giveaways to customers who request products.

Baseline Efficiencies

The baseline is no restriction valve in place.

Efficient Equipment

The efficient condition is a thermostatically initiated shower restriction valve used in conjunction with a standard showerhead.

Algorithms

Electric Demand Savings

ΔkW = ΔkWh/HOURS

Symbol Table

Electric Energy Savings

ΔkWh = ((GPM × WasteTime × # people × # showers × usedays/year / SH/home × 8.3 × 1.0 × ($TEMP_{sh}$ - $TEMP_{in}$)) / ηElectric_DHW / 3,412) x ISR x %Electric_DHW

Symbol Table

Fossil Fuel Savings

ΔMMBtu = ((GPM × WasteTime × # people × # showers × usedays/year / SH/home × 8.3 × 1.0 × ($TEMP_{sh}$ - $TEMP_{in}$)) / ηFuel_DHW / 1,000,000) x ISR x %Fuel_DHW

Symbol Table

Water Savings

ΔCCF = GPM × WasteTime × # people × # showers × usedays/year/ SH/home / 748 x ISR

Where:

# people	=	Average number of people per household = 2.33[2]
# showers	=	Showers per person per day = 0.6[3]
%Electric_DHW	=	Proportion of water heating supplied by electricity = 25%[4]
%Fuel_DHW	=	Proportion of water heating supplied by fuel oil, natural gas, or propane[4] Fuel Oil: 20%; Natural Gas: 26%; Propane: 27%
ΔCCF	=	Gross customer annual water savings for the measure See Reference Tables section for deemed savings values.
ΔkW	=	Gross customer connected load kW savings for the measure See Reference Tables section for deemed savings values.
ΔkWh	=	Gross customer annual kWh savings for the measure See Reference Tables section for deemed savings values.
ΔMMBtu	=	Gross customer annual MMBtu savings for the measure See Reference Tables section for deemed savings values.
ηElectric_DHW	=	Recovery efficiency of electric water heater = 0.98[5]
ηFuel_DHW	=	Recovery efficiency of fuel water heater = 0.78[12]
1,000,000	=	Conversion factor from Btu to MMBtu
1.0	=	Specific heat of water (Btu/lb-°F) (constant)
3,412	=	Conversion factor from Btu to kWh
748	=	Constant to convert from gallons to CCF
8.3	=	Constant to convert gallons to lbs
GPM	=	Flow rate (gpm) of showerhead = 2.5 gpm[6]

HOURS	=	Annual full load hours = 3,427.1 hours[1]
ISR	=	In service rate, or the percentage of units rebated that are actually installed = 45%[7]
SH/home	=	Average number of showerheads per household = 1.3[8]
$TEMP_{in}$	=	Assumed temperature of water entering house = 51.9 F[9]
$TEMP_{sh}$	=	Assumed temperature of water coming from showerhead = 101 F[10]
usedays/year	=	Days showerhead is used per year = 365
WasteTime	=	Average hot water waste time (minutes) avoided per shower due to restriction valve = 0.88[11]

Load Shapes

For DHW systems not on Utility Controlled DHW program (Default): Loadshape #8, Residential DHW Conservation;

For DHW systems on Utility Controlled DHW program: Loadshape #54, Controlled DHW Conservation;

Loadshapes #8 and #54 are based on Itron 8760 hourly load data.

8a Residential DHW conserve
54a Controlled DHW Conservation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7%	29.1%	14.3%	7.9%	40.1%	20.3%
54	Controlled DHW Conservation	Active	48.7%	29.1%	14.3%	7.9%	20.5%	12.1%

Net Savings Factors

Measures

HWESHTRV	Thermostatically Initiated Shower Restriction Valve

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	HWESHTRV	0.90	1.00
LISF Retrofit	6034LISF	HWESHTRV	1.00	1.00

Lifetimes

The measure life is assumed to be 10 years.[13]

Measure Cost

The measure cost for free giveaways is the actual program cost of a new shower valve: $16.75.

Reference Tables

Savings are presented below.[14]

ΔkW	ΔkWh	ΔMMBtu (fuel oil)	ΔMMBtu (natural gas)	ΔMMBtu (propane)	ΔCCF
0.00345	11.8	0.041	0.053	0.055	0.52

Footnotes

[1] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[3] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 8.

[4] DHW fuel percentages for free products based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

Note that during November 2017 TAG, EVT and DPS agreed that assumptions for HPWH will be added during the next TRM reliability update cycle in 2020.

[6] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

[7] In the absence of evaluation studies supporting an ISR for free shower restriction valves, EVT began with the ISR assumption for low-flow showerheads (56%) from the Home Energy Kits measure: "Average of showerhead in service rate for kits including one showerhead (65%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits showerhead in service rate for single family homes (47%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23." EVT reduced the ISR to 45% for shower restriction valves since customers are likely to be less familiar with these products.

[8] Average of values for single family and multifamily households from Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 12, Table 9.

[9] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.

[10] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

[11] Average of values from Troy Sherman, "Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based on Data from Lawrence Berkeley National Labs," August 11, 2014, p. 11 and Cadmus and PPL Electric, "Pilot Study for a Thermostatic Shower Restriction Valve," 2015, p. 6, Table 4.

[12] Based on a review of fuel DHW systems available in AHRI database.

[13] California DEER Ex Ante Database

[14] See file EVT_Shower Restriction Valve_Analysis_Feb 2018_v2.xlsx for calculation details.

Low Flow Faucet Aerator

Measure Number: RS-DHW-LFFA a
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Existing Homes
End Use: Hot Water

Update Summary

The following additiongs have been made:

- Dropship program and associated ISR assumption
- Additional options for each program:
  - Electric HPWH
  - Unknown Electric DHW
  - Unknown DHW
- Updated ISR for free products:
  - Included Kitchen Aerator ISR from Navigant Evaluation Report

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- Cadmus_Showerhead and Faucet Aerator Meter Study_June 2013
- Navigant_energySMART Energy Savings Kits_Apr 2016
- Navigant_Measures and Assumptions for Demand Side Management Planning_Apr 2009
- Schultdt_Energy Related Water Fixture Measurements_2008
- EVT_Low Flow Faucet Aerators_Analysis_June 2017_v5
- NMR_VT SF Existing Homes Onsite Report - FINAL 072018
- 10 CFR § 430_32 - Energy and water conservation standards
- AHRI_SearchResults_Residential Water Heaters_HPwTank_2021
- AHRI_SearchResults_Residential Water Heaters_2021
- DOE_EERE_Std_DHW_events_2014_05_20_VT
- EVT Data CUBE 2021
- US Census_2019_ACS_5YR_DP04_VT
- EVT - Analysis_RES Low Flow Faucet Aerators_2021 - Final

Description

This measure relates to the installation of a low flow faucet aerator in a single family home or multifamily building. Low flow faucet aerators reduce the consumption of hot water and as a result, the energy required to heat it.

The measure applies to:

- Retrofit direct install implementation
- Free giveaways through Vermont Foodbanks
- The Dropship program - product is ordered via the EVT website by building owners, weatherization contractors or EVT staff. A distributor ships the products to the customer, free of charge. The building owner must confirm that the product will be installed and EVT reserve the right to inspect at a later date.

Algorithms

Electric Demand Savings

$\Delta kW = \Delta kWh / HOURS$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((((GPM_{exist} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Tperson/day \times \# people \times usedays/year \times DR) \times 8.3 \times 1.0 \times (TEMP_{faucet} - TEMP_{in}) / \eta Electric\_DHW / 3,412) \times ISR \times \%Electric\_DHW$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu = ((((GPM_{exist} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Tperson/day \times \# people \times usedays/year \times DR \times 8.3 \times 1.0 \times (TEMP_{faucet} - TEMP_{in}) / 1,000,000 / \eta Fuel\_DHW) \times ISR \times \%Fuel\_DHW$

Symbol Table

Water Savings

$\Delta CCF = ((GPM_{exist} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Tperson/day \times \# people \times usedays/year \times DR / 748 \times ISR$

Where:

people = Average number of people per household

= 2.30[2]

%Electric_DHW = Proportion of water heating supplied by electricity

=100% if electric DHW system,

0% if non-electric DHW system

= 27%[3] when DHW fuel type is unknown, or for free products at Vermont Foodbanks

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane

= 100% if fuel DHW system,

0% if non-fuel DHW system

= When DHW fuel type is unknown, or for free products at Vermont Foodbanks, assume:[3]

Fuel Oil	Natural Gas	Propane
27%	13%	33%

ΔCCF = Gross customer annual water savings for the measure, in hundreds of cubic feet

See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure

See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure

See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure

See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater. The Unknown Electric GHW value is a Weighted average of Electric Water Heaters in VT. Quantity of HPWH was derived from EVT Program data and NMR Report on Single Family homes in VT[4].

System Type	Recovery Efficiency

Electric Resistance	0.98[5]
Electric HPWH	3.49[6]
Unknown Electric DHW	1.71

ηFuel_DHW	=	Recovery efficiency of fuel water heater = 0.83[15]
1,000,000	=	Conversion factor from Btu to MMBtu
1.0	=	Specific heat of water (Btu/lb-°F) (constant)
3,412	=	Conversion factor from Btu to kWh
748	=	Constant to convert from gallons to CCF
8.3	=	Constant to convert gallons to lbs
DR	=	Percentage of water flowing down drain = 63%[7]
GPM_{exist}	=	Flow rate (gpm) of existing faucet = 2.2[8]
GPM_{low}	=	Flow rate (gpm) of low flow faucet = 1.0 or 1.5 gpm for Direct Install = 1.5 gpm for free products
HOURS	=	Annual full load hours = 3,427.1 hours[1]
ISR	=	In service rate, or the percentage of units rebated that are actually installed = 100% for Direct Install = 62%[9] for free products = 90%[10] for Dropship
$TEMP_{faucet}$	=	Assumed temperature of water used by faucet = 88 F[11]
$TEMP_{in}$	=	Assumed temperature of water entering house = 51.8 F[12]
$Throttle_{base}$	=	Ratio of user setting to full-throttle flow rate for baseline faucet = 0.83[13]
$Throttle_{low}$	=	Ratio of user setting to full-throttle flow rate for low flow faucet = 0.95[13]
Tperson/day	=	Average daily length of use per person, per faucet (min/person/faucet) = 1.6[14]
usedays/year	=	Days faucet used per year = 365 days

Baseline Efficiencies

The baseline is assumed to be a standard faucet aerator with a flow rate of 2.2 gpm. Savings assumptions include a 0.83 throttling factor for baseline faucets[13] to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 1.83 gpm.

High Efficiency

The efficient condition is a faucet aerator with a flow rate of either 1.0 gpm or 1.5 gpm for direct install programs and 1.5 gpm for free giveaways. Savings assumptions include a 0.95 throttling factor for new faucets[13] to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 0.95 gpm for 1.0 gpm aerators and 1.4 gpm for 1.5 gpm aerators.

Load Shapes

For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

Loadshapes #8 and #54 are based on Itron 8760 hourly load data.

8a Residential DHW conserve
54a Controlled DHW Conservation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7%	29.1%	14.3%	7.9%	40.1%	20.3%
54	Controlled DHW Conservation	Active	48.7%	29.1%	14.3%	7.9%	20.5%	12.1%

Net Savings Factors

Measures

HWEFAUCT	Faucet aerator/flow restrictor

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
6032LIEP [6032EPEP]	Efficient Products - Low Income

Persistence

The persistence factor is assumed to be one.

Lifetimes

The measure life is assumed to be 10 years.[16]

Analysis period is the same as the lifetime.

Measure Cost

The measure cost for direct install is the actual cost (material and labor) of installing the new aerator[17] = $13, if actual is unknown.

The measure cost for free giveaways and the dropship program is the actual program cost[18] of a new aerator = $2, if actual is unknown.

The measure cost for the Tailored Communities Energy Savings Kit componments are the actual program cost:

Flow Rate	Location	Model	Manufacturer	Cost per unit
1.0	Bathroom	N3210B-PC	AMC	$1
1.5	Kitchen	N3115P	AMC	$2

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Reference Tables

Savings are presented below, depending on program type.[19]

Program Type	DHW Fuel and Flow Rate	ΔkW	ΔkWh	ΔMMBtu (fuel oil)	ΔMMBtu (natural gas)	ΔMMBtu (propane)	ΔCCF	ITEM CODES
Direct Install	Electric Resistance, 1.0 GPM	0.01944	66.6				0.99	DHWFAERATOR2 DHWFAERATMF2 LIDHWFAERATOR2
	Electric HPWH, 1.0 GPM	0.00546	18.7				0.99	DHWFAERATORHP2 DHWFAERATMFHP2 LIDHWFAERATORHP2
	Unknown Electric, 1.0 GPM	0.01107	38.0				0.99	DHWFAERATORUE2 DHWFAERATMFUE2 LIDHWFAERATORUE2
	Oil, 1.0 GPM			0.268			0.99	DHWFAERATOROL2 DHWFAERATMFOL2 LIDHWFAERATOROL2
	Natural Gas, 1.0 GPM				0.268		0.99	DHWFAERATORNG2 DHWFAERATMFNG2 LIDHWFAERATORNG2
	Propane, 1.0 GPM					0.268	0.99	DHWFAERATORPR2 DHWFAERATMFPR2 LIDHWFAERATORPR2
	Unknown, 1.0 GPM	0.00299	10.2	0.072	0.035	0.089	0.99	DHWFAERATORUK2 DHWFAERATMFUK2 LI-AERAT-UNK1
	Electric Resistance, 1.5 GPM	0.00890	30.5				0.45	DHWFAERATOR DHWFAERATMF
	Electric HPWH, 1.5 GPM	0.00250	8.6				0.45	DHWFAERATORHP DHWFAERATMFHP
	Unknown Electric, 1.5 GPM	0.00507	17.4				0.45	DHWFAERATORUE DHWFAERATMFUE
	Oil, 1.5 GPM			0.123			0.45	DHWFAERATOROL DHWFAERATMFOL
	Natural Gas, 1.5 GPM				0.123		0.45	DHWFAERATORNG DHWFAERATMFNG
	Propane, 1.5 GPM					0.123	0.45	DHWFAERATORPR DHWFAERATMFPR
	Unknown, 1.5 GPM	0.00137	4.7	0.033	0.016	0.041	0.45	DHWFAERATORUK DHWFAERATMFUK LI-AERAT-UNK2
Dropship	Electric Resistance, 1.0 GPM	0.01749	59.9				0.89	DHWFAERATOR2DS DHWFAERATLI2DS
	Electric HPWH, 1.0 GPM	0.00491	16.8				0.89	DHWFAERATORHP2DS DHWFAERATLIHP2DS
	Unknown Electric, 1.0 GPM	0.00997	34.2				0.89	DHWFAERATORUE2DS DHWFAERATLIUE2DS
	Oil, 1.0 GPM			0.242			0.89	DHWFAERATOROL2DS DHWFAERATLIOL2DS
	Natural Gas, 1.0 GPM				0.242		0.89	DHWFAERATORNG2DS DHWFAERATLING2DS
	Propane, 1.0 GPM					0.242	0.89	DHWFAERATORPR2DS DHWFAERATLIPR2DS
	Unknown, 1.0 GPM	0.00269	9.2	0.065	0.031	0.080	0.89	DHWFAERATORUK2DS DHWFAERATLIUK2DS
	Electric Resistance, 1.5 GPM	0.00801	27.4				0.41	DHWFAERATORDS DHWFAERATLIDS
	Electric HPWH, 1.5 GPM	0.00225	7.7				0.41	DHWFAERATORHPDS DHWFAERATLIHPDS
	Unknown Electric, 1.5 GPM	0.00456	15.6				0.41	DHWFAERATORUEDS DHWFAERATLIUEDS
	Oil, 1.5 GPM			0.119			0.41	DHWFAERATOROLDS DHWFAERATLIOLDS
	Natural Gas, 1.5 GPM				0.119		0.41	DHWFAERATORNGDS DHWFAERATLINGDS
	Propane, 1.5 GPM					0.119	0.41	DHWFAERATORPRDS DHWFAERATLIPRDS
	Unknown, 1.5 GPM	0.00123	4.2	0.030	0.014	0.036	0.41	DHWFAERATORUKDS DHWFAERATLIUKDS
Free Products	Unknown, 1.5 GPM	0.00085	2.9	0.021	0.010	0.025	0.28	LIFDBNK-HAERATE

Footnotes

[1] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((70.8% * 2.41) + (29.2% * 2.04)) based on 2015-2019 American Community Survey 5-Year Estimates for Vermont. See reference file US Census_2019_ACS_5YR_DP04_VT.csv.

[3] DHW fuel percentages for free products based on data received by Efficiency Vermont from the 2018 NMR Group "Vermont Single-Family Existing Homes On-Site Report", Table 59.

[4] Please see EVT Data CUBE 2021.xlsx for EVT Program data on HPWH quantities in VT. Please see Table 6 of the NMR Group "Vermont Single-Family Existing Homes On-Site Report", which supports a value of 171,322 own-occupied single-family homes in VT. Applying the 27% of homes with Electric Water Heating, as found in table 59 of the report, results in 33,134 VT Homes with Electric Resistance Water Heaters and 13,590 VT homes with Electric Heat Pump Water Heaters.

[5] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

Note that during November 2017 TAG, EVT and DPS agreed that assumptions for HPWH will be added during the next TRM reliability update cycle in 2020.

[6] Review of AHRI database shows that Electric Heat Pump Water Heaters have a recovery efficiency of 348.56%. For the raw data, please see AHRI_SearchResults_Residential Water Heaters_HPwTank_2021.xlsx.

[7] Because faucet usages are at times dictated by volume (for example, filling a sink to wash dishes), only usage that would allow water to go straight down the drain will provide savings. DR values are from Navigant Consulting, Inc. for the Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning, Appendix C: Substantiation Sheets," April 16, 2009, pages C-57 and C-61. DR values weighted by typical number of kitchen faucets (1 faucet) and bath faucets (2 faucets) in a household: (1/3 * 0.50) + (2/3* 0.70) = 0.63.

[8] Federal standard for faucets, 10 CFR § 430.32 - Energy and water conservation standards (o) faucets

[9] Average of Bathroom & Kitchen Aerator in service rates (63% & 60%, respectively) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20. This was based off of a Telephone Survey from PY4, weighted by strata.

[10] Dropship is estimated higher than free giveaway product as the building owner or contractor is required to actively order the required product online,

confirm that it will be installed and EVT may inspect the installation at a later date. However since the installation is not performed by EVT staff or contractor (as in direct install), a 10% discount is applied.

[11] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, Table 7, page 11. $TEMP_{faucet}$ values weighted by typical number of kitchen faucets (1 faucet) and bath faucets (2 faucets) in a household: (1/3 * 93) + (2/3* 86) = 88.

[12] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014. Values found on Weather Inputs sheet on spreadsheet. http://energy.gov/eere/buildings/downloads/building-america-standard-dhw-schedules

Please see DOE_EERE_Std_DHW_events_2014.05.20_VT.xlsm

[13] Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[14] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, Table 6, page 10.

[15] Review of AHRI database shows that Gas Residential Water Heaters (with Active AHRI certifications, Natural Gas, Fuel Oil & Propane Gas included) have an average recovery efficiency of 83%. Accessed February 2021.

[16] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[17] A full install cost of $13 is based on market research average of $6 for faucet aerator and assess and install cost of $7, based on 20 minutes of labor at $20/hour.

[18] Data from EVT program manager was $1.75. Rounded to $2 to account for labor & shipping costs.

[19] See file EVT Analysis file for calculation details.

Low Flow Showerhead

Measure Number: RS-DHW-LFSH a
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Existing Homes
End Use: Hot Water

Update Summary

The following additiongs have been made:

- Dropship program added, and associated ISR assumption
- Additional options for each program:
  - Electric HPWH
  - Unknown Electric DHW
  - Unknown DHW

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Cadmus_Showerhead and Faucet Aerator Meter Study_June 2013
- Navigant_energySMART Energy Savings Kits_Apr 2016
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- NMR_VT SF Existing Homes Onsite Report - FINAL 072018
- 10 CFR § 430_32 - Energy and water conservation standards
- AHRI_SearchResults_Residential Water Heaters_HPwTank_2021
- AHRI_SearchResults_Residential Water Heaters_2021
- DOE_EERE_Std_DHW_events_2014_05_20_VT
- EPA_WaterSense Labeled Products_Feb 2021
- EVT Data CUBE 2021
- evt-rnc-dhw-eff-calculation_Feb 2021
- US Census_2019_ACS_5YR_DP04_VT
- Analysis_RES Low Flow Showerhead_2020 - EVT Final

Description

This measure characterizes the installation of a low-flow showerhead in a single family home or a multifamily building. The qualifying efficient flow rate for the direct install, dropship and free giveaway programs is 1.5 gallons per minute (gpm). For the RNC program, the qualifying flow rate is a WaterSense-labeled showerhead. As of February 2021, the average WaterSense labeled efficient showerhead flow rate is 1.8 gpm. The measure applies to RNC, retrofit direct install implementation, dropship program, or free giveaways to customers who request products.

Algorithms

Electric Demand Savings

ΔkW = ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh = $((GPM_{base} - GPM_{low}) \times Tshower \times \#\ people \times \#\ showers \times usedays/year / SH/home \times 8.3 \times 1.0 \times (TEMP_{sh} - TEMP_{in}) / \eta Electric\_DHW / 3,412) \times ISR \times \%Electric\_DHW$

Symbol Table

Fossil Fuel Savings

ΔMMBtu = $((GPM_{base} - GPM_{low}) \times Tshower \times \#\ people \times \#\ showers \times usedays/year / SH/home \times 8.3 \times 1.0 \times (TEMP_{sh} - TEMP_{in}) / \eta Fuel\_DHW / 1,000,000) \times ISR \times \%Fuel\_DHW$

Symbol Table

Water Savings

ΔCCF = $((GPM_{base} - GPM_{low}) \times Tshower \times \#\ people \times \#\ showers \times usedays/year / SH/home / 748) \times ISR$

Where:

people = Average number of people per household
= 2.30[2]

showers = Showers per person per day
= 0.6[3]

%Electric_DHW = For direct install, Dropship or RNC, 100% if electric DHW system, 0% if non-electric DHW system
= 27%[4] for free giveaways, or unknown fuel DHW systems

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane
= For Direct Install, Dropship or RNC, 100% if fuel DHW system, 0% if non-fuel DHW system
= For free products, or unknown fuel DHW systems, assume:[4]

Fuel Oil	Natural Gas	Propane
27%	13%	33%

ΔCCF = Gross customer annual water savings for the measure
See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure
See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure
See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure
See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater. The Unknown Electric GHW value is a Weighted average of Electric Water Heaters in VT. Quantity of HPWH was derived from EVT Program data and NMR Report on Single Family homes in VT[5].

System Type	Recovery Efficiency
Electric	0.98[6]

Resistance	
Electric HPWH	3.49[7]
Unknown Electric DHW	1.71

ηFuel_DHW	=	Recovery efficiency of fuel water heater = 0.83[19] for direct install, dropship or free giveaways = 0.89[20] for RNC
1,000,000	=	Conversion factor from Btu to MMBtu
1.0	=	Specific heat of water (Btu/lb-°F) (constant)
3,412	=	Conversion factor from Btu to kWh
748	=	Constant to convert from gallons to CCF
8.3	=	Constant to convert gallons to lbs
GPM_{base}	=	Flow rate (gpm) of baseline showerhead = 2.5 gpm for direct install, dropship or free giveaways[8] = 2.4 gpm for RNC[9]
GPM_{low}	=	Flow rate (gpm) of low flow showerhead = 1.5 gpm for direct install, dropship or free giveaways[10] = 1.8 gpm for RNC[11]
HOURS	=	Annual full load hours = 3,427.1 hours[1]
ISR	=	In service rate, or the percentage of units rebated that are actually installed = 100% for direct install or RNC = 56%[12] for free products = 90%[13] for Dropship
SH/home	=	Average number of showerheads per household = 1.3 for existing homes or multifamily buildings[14] = 2.1 for RNC[15]
$TEMP_{in}$	=	Assumed temperature of water entering house = 51.8 F[16]
$TEMP_{sh}$	=	Assumed temperature of water coming from showerhead = 101 F[17]
Tshower	=	Average shower length in minutes = 7.8[18]
usedays/year	=	Days showerhead is used per year = 365

Baseline Efficiencies
The baseline for direct install or free giveaways is a standard showerhead using 2.5 gpm. The baseline for RNC is a showerhead with a flow rate of 2.4 gpm.[9]

High Efficiency
The efficient condition for direct install or free giveaways is a showerhead with a flow rate of 1.5 gpm. The efficient condition for RNC is a showerhead with a flow rate of 1.8 gpm.[11]

Load Shapes
For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

Loadshapes #8 and #54 are based on Itron 8760 hourly load data.

8a Residential DHW conserve
54a Controlled DHW Conservation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7%	29.1%	14.3%	7.9%	40.1%	20.3%
54	Controlled DHW Conservation	Active	48.7%	29.1%	14.3%	7.9%	20.5%	12.1%

Net Savings Factors

Measures

HWESHOWR	Low flow showerhead

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES

Persistence
The persistence factor is assumed to be one.

Lifetimes
The measure life is assumed to be 10 years.[21]

Analysis period is the same as the lifetime.

Measure Cost

The measure cost for direct install is the actual cost (material and labor) of installing the new showerhead[22] = $22, or $27 for handheld options

The measure cost for free giveaways and the dropship program is the actual program cost[23] of a new showerhead: $4

The measure cost for the Tailored Communities program is the actual program cost[24] of a showerhead: $24

The incremental measure cost for RNC is $6[25].

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Reference Tables

Savings are presented below, depending on program type & DHW Fuel Source.[26]

Program Type	***DHW Fuel***	***ΔkW***	***ΔkWh***	***ΔMMBtu (fuel oil)***	***ΔMMBtu (natural gas)***	***ΔMMBtu (propane)***	***ΔCCF***	***ITEM CODES***
Direct Install	Electric Resistance	0.10770	369.1				4.04	DHWSHOWERHD DHWSHOWERMF LIDHWSHOWERHD
	Electric HPWH	0.03024	103.6				4.04	DHWSHOWERHDHP DHWSHOWERMFHP LIDHWSHOWERHDHP
	Unknown Electric	0.06136	210.3				4.04	DHWSHOWERHDUE DHWSHOWERMFUE LIDHWSHOWERHDUE
	Oil			1.487			4.04	DHWSHOWERHDOL DHWSHOWERMFOL LIDHWSHOWERHDOL
	Natural Gas				1.487		4.04	DHWSHOWERHDNG DHWSHOWERMFNG LIDHWSHOWERHDNG
	Propane					1.487	4.04	DHWSHOWERHDPR DHWSHOWERMFPR LIDHWSHOWERHDPR
	Unknown	0.01657	56.8	0.401	0.193	0.491	4.04	DHWSHOWERHDUK DHWSHOWERMFUK LIDHWSHOWERHDUK
RNC	Electric Resistance	0.04098	140.4				1.54	DHWSHWERRNC
	Electric HPWH	0.01151	39.4				1.54	DHWSHWERHPRNC
	Unknown Electric	0.02335	80.0				1.54	DHWSHWERUERNC
	Oil			0.528			1.54	DHWSHWEROLRNC
	Natural Gas				0.528		1.54	DHWSHWERNGRNC
	Propane					0.528	1.54	DHWSHWERPRRNC
	Unknown	0.00630	21.6	0.142	0.069	0.174	1.54	DHWSHWERUKRNC
Dropship	Electric Resistance	0.09693	332.2				3.64	DHWSHOWERDS LIDHWSHOWERDS
	Electric HPWH	0.02722	93.3				3.64	DHWSHOWERDSHP LIDHWSHOWERDSHP
	Unknown Electric	0.05523	189.3				3.64	DHWSHOWERDSUE LIDHWSHOWERDSUE
	Oil			1.338			3.64	DHWSHOWERDSOL LIDHWSHOWERDSOL
	Natural Gas				1.338		3.64	DHWSHOWERDSNG LIDHWSHOWERDSNG
	Propane					1.338	3.64	DHWSHOWERDSPR LIDHWSHOWERDSPR
	Unknown	0.01491	51.1	0.361	0.174	0.442	3.64	DHWSHOWERDSUK LIDHWSHOWERDSUK
Free Products	Unknown	0.00928	31.8	0.225	0.108	0.275	2.26	LIFDBNKSHWERHD

Footnotes

[1] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((70.8% * 2.41) + (29.2% * 2.04)) based on 2015-2019 American Community Survey 5-Year Estimates for Vermont. See reference file US Census_2019_ACS_5YR_DP04_VT.csv.

[3] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 8.

[4] DHW fuel percentages based on data received by Efficiency Vermont from the 2018 NMR Group "Vermont Single-Family Existing Homes On-Site Report", Table 59.

[5] Since the vast majority of Electric HPWH in VT have come through EVTs programs, a fair estimate of the number of HPWH in VT would equate the number of units captured in this program data. Since the introduction of this measure in 2011, there have been 13,605 units throughout various projects as of March 9, 2021. Please see **EVT Data CUBE 2021.xlsx** for EVT Program data.

In order to determine the quantity of Electric Resistance DHW Systems in Residences of VT, we used this program data, along with the **NMR Group "Vermont Single-Family Existing Homes On-Site Report"**. Using the percentage of homes in VT with electric water heating (27% per Table 59), along with the quantity of owner-occupied single-family homes in VT (171,322 per Table 6), then subtracting the Electric HPWH units in VT, we calculated 33,119 Single-family homes in Vermont with Electric Resistance water heaters.

Using the Recovery Efficiencies for these systems, along with the calculated quantities of units in VT, we then calculated a weighted average Recovery Efficiency to use in situations where the type of Electric Water Heater is unknown.

[6] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

[7] Review of AHRI database shows that Electric Heat Pump Water Heaters have a recovery efficiency of 348.56%. For the raw data, please see AHRI_SearchResults_Residential Water Heaters_HPwTank_2021.xlsx.

[8] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm), which is the minimum qualifying flow rate for Efficiency Vermont direct install programs. Baseline flow rate is verified on site by reviewing the equipment label and measuring the flow rate. However, baseline flow rates are not recorded.

[9] Average showerhead flow rate in new single-family homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 11, Table 6.

[10] Flow rate of showerhead provided by program.

[11] Efficient showerhead flow rate for RNC is the average flow rate of products on the WaterSense Labeled Products list as of February 12, 2021. See file EPA_WaterSense Labeled Products_Feb 2021.xlsx.

[12] Average of showerhead in service rate for kits including one showerhead (65%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits showerhead in service rate for single family homes (47%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[13] Dropship is estimated higher than free giveaway product as the building owner or contractor is required to actively order the required product online, confirm that it will be installed and EVT may inspect the installation at a later date. However since the installation is not performed by EVT staff or contractor (as in direct install), a 10% discount is applied.

[14] Average of values for single family and multifamily households from Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 12, Table 9.

[15] Average number of low-flow showerheads from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 12. Low flow is defined in the RNC report as 2.5 GPM, which is the maximum flow rate established by the Energy Policy Act of 1992 (EPAct). Since the saturation rate of low-flow showerheads is 98% for new homes in EVT territory (Table 8, page 13), EVT assumes 2.1 showerheads/home is a reasonable assumption for RNC. *Please see NMR_VT RNC Baseline SF Onsite Report Draft_051217.docx*

[16] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014. Values found on Weather Inputs sheet on spreadsheet. http://energy.gov/eere/buildings/downloads/building-america-standard-dhw-schedules

Please see DOE_EERE_Std_DHW_events_2014.05.20_VT.xlsm

[17] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

[18] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 10, Table 6.

[19] Review of AHRI database shows that Gas Residential Water Heaters (with Active AHRI certifications, Natural Gas, Fuel Oil & Propane Gas included) have an average recovery efficiency of 83%. Accessed February 2021.

[20] The fuel DHW system recovery efficiency for RNC is a weighted average based on the distribution of DHW system types in new homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017. Energy factors from the Vermont RNC report were converted to recovery efficiencies using information from the AHRI database, accessed January 2018. See EVT Analysis file for details.

[21] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[22] Actual program cost + assumed labor of approximately $7 ($20/hr, for 20 mins). Actual prgoram cost is either $15 or, for the hand-held version, $20.

[23] Data from EVT program manager was $3.65.

[24] Cost estimate provided by program, for a 1.5 GPM Showerhead with Thermostatically Restricted Valve, Model #EV3011-CP150-SB, manufactered by Evolve.

[25] Incremental Cost, Based on a comparison of WaterSense & non-WaterSense qualified products available on HomeDepot.com during March 2021. See EVT Analysis file for details.

[26] See file EVT Analysis file for calculation details.

Pipe Wrap

Measure Number: RS-DHW-PWRP a
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Existing Homes
End Use: Hot Water

Update Summary

The following changes have been made:

- Dropship program added, and associated ISR assumption
- Additional options for each program:
  - Electric HPWH
  - Unknown Electric DHW
- Product specifications, from program data:
  - Measure Cost
  - R-value
  - Length of pipe
  - Diameter of pipe
  - Thickness of insulation material

Referenced Documents

- Measures and Assumptions for DSM Planning Appendix C Substantiation Sheets
- DEER2014-EUL-table-update_2014-02-05.xlsx
- NMR_VT SF Existing Homes Onsite Report - FINAL 072018
- AHRI_SearchResults_Residential Water Heaters_HPwTank_2021
- AHRI_SearchResults_Residential Water Heaters_2021
- EVT Data CUBE 2021
- EVT Program Information 2021_Pipe Pre-Slit Insulation 1 foot _ ICF Contractor Store
- EVT - Analysis_RES Pipe Wrap_2021 - Final

Description

Insulation is added to both the hot and cold uninsulated pipes from the hot water tank to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses. This measure applies to retrofit direct install implementation at a residential location.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / 8,760

Symbol Table

Electric Energy Savings

ΔkWh	$= ((C_{exist} / R_{exist} - C_{new} / R_{new}) \times L \times \Delta T \times 8{,}760 \times ISR) / \eta Electric\_DHW / 3{,}412$

Symbol Table

Fossil Fuel Description

ΔMMBtu	$= ((C_{exist} / R_{exist} - C_{new} / R_{new}) \times L \times \Delta T \times 8{,}760 \times ISR) / \eta Fuel\_DHW / 1{,}000{,}000$

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

ΔMMBtu = Gross customer annual MMBtu savings for the measure

ΔT = Average temperature difference between supplied water and outside air temperature (°F).
55°F[1]

ηElectric_DHW = Recovery efficiency of electric water heater. The Unknown Electric DHW value is a Weighted average of Electric Water Heaters in VT. Quantity of HPWH was derived from EVT Program data and NMR Report on Single Family homes in VT[2].

System Type	Recovery Efficiency
Electric Resistance	0.98[3]
Electric HPWH	3.49[4]
Unknown Electric	1.71

ηFuel_DHW = Recovery efficiency of fuel water heater
= 0.83[11]

1,000,000 = Conversion factor from Btu to MMBtu

3,412 = Conversion factor from Btu to kWh

8,760 = Hours per year

C_{exist} = Circumference (ft) of uninsulated pipe[5]

Diameter pipe (in)	Circumference (ft)
0.5"	0.131
0.75"	0.196

C_{new} = Circumference (ft) of insulated pipe[6]

Diameter pipe (in)	thickness of foam (in)	Circumference (ft)
0.5"	3/8"	0.327
0.75"	1/2"	0.458

ISR = In service rate, or the percentage of units rebated that are actually installed
= 100% for Direct Install
= 90%[7] for Dropship

L = Length of pipe from water heating source covered by pipe wrap (ft)
= 7 ft[8]

R_{exist} = Pipe heat loss coefficient of uninsulated pipe [(hr-°F-ft²)/Btu]
= 1.0[9]

R_{new} = Pipe heat loss coefficient of newly insulated pipe [(hr-°F-ft)/Btu]
= 1.0 + R value of insulation[10]
= 4.2

Baseline Efficiencies
The baseline condition is an uninsulated, domestic hot or cold water pipe.

High Efficiency
The high efficiency condition is a domestic hot or cold water pipe with R-3.2 pipe wrap installed on the hot or cold water pipes up to the first elbow.

Load Shapes
7a Residential DHW insulation
53a Controlled DHW Insulation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%
53	Controlled DHW Insulation	Active	31.7%	34.9%	15.9%	17.5%	51.0%	59.4%

Net Savings Factors
Measures

HWEPIPES	Insulate hot water pipes

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Persistence
The persistence factor is assumed to be one.

Lifetimes
12 years[12]

Analysis period is the same as the lifetime.

Measure Cost
The measure cost is the actual program cost of installing the pipe wrap: $2[13]

O&M Cost Adjustments
There are no operation and maintenance cost adjustments for this measure.

Reference Table
Savings are presented below, depending on program type & DHW Fuel Source.[14]

Program Type	DHW Fuel	ΔkW	ΔkWh	ΔMMBtu (fuel oil)	ΔMMBtu (natural gas)	ΔMMBtu (propane)	ITEM CODES
Direct Install	Electric Resistence	0.00612	53.6				DHWPIPEINSU LIDHWPIPEINSU
	Electric HPWH	0.00172	15.1				DHWPIPEINSUHP LIDHWPIPEINSUHP
	Unknown Electric	0.00349	30.5				DHWPIPEINSUUE LIDHWPIPEINSUUE
	Oil			0.216			DHWPIPEINSUOL LIDHWPIPEINSUOL
	Natural Gas				0.216		DHWPIPEINSUNG LIDHWPIPEINSUNG
	Propane					0.216	DHWPIPEINSUPR LIDHWPIPEINSUPR
	Unknown	0.00094	8.2	0.059	0.028	0.070	DHWPIPEINSUUK LIDHWPIPEINSUUK
Dropship	Electric Resistence	0.00551	48.2				DHWPIPEINDS LIDHWPIPEINDS
	Electric HPWH	0.00155	13.6				DHWPIPEINDSHP LIDHWPIPEINDSHP
	Unknown Electric	0.00314	27.5				DHWPIPEINDSUE LIDHWPIPEINDSUE
	Oil			0.194			DHWPIPEINDSOL LIDHWPIPEINDSOL
	Natural Gas				0.194		DHWPIPEINDSNG LIDHWPIPEINDSNG
	Propane					0.194	DHWPIPEINDSPR LIDHWPIPEINDSPR
	Unknown	0.00085	7.4	0.053	0.025	0.063	DHWPIPEINDSUK LIDHWPIPEINDSUK

Footnotes
[1] Assumes 120°F water leaving the hot water tank and average temperature of basement of 65°F.

[2] Since the vast majority of Electric HPWH in VT have come through EVTs programs, a fair estimate of the number of HPWH in VT would equate the number of units captured in this program data. Since the introduction of this measure in 2011, there have been 13,605 units throughout various projects as of March 9, 2021. Please see **EVT Data CUBE 2021.xlsx** for EVT Program data.

In order to determine the quantity of Electric Resistance DHW Systems in Residences of VT, we used this program data, along with the **NMR Group "Vermont Single-Family Existing Homes On-Site Report"**. Using the percentage of homes in VT with electric water heating (27% per Table 59), along with the quantity of owner-occupied single-family homes in VT (171,322 per Table 6), then subtracting the Electric HPWH units in VT, we calculated 33,119 Single-family homes in Vermont with Electric Resistance water heaters.

Using the Recovery Efficiencies for these systems, along with the calculated quantities of units in VT, we then calculated a weighted average Recovery Efficiency to use in situations where the type of Electric Water Heater is unknown.

[3] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

[4] Review of AHRI database shows that Electric Heat Pump Water Heaters have a recovery efficiency of 348.56%. For the raw data, please see AHRI_SearchResults_Residential Water Heaters_HPwTank_2021.xlsx.

[5] C = Diameter (in) * π/12.

For a 0.5" pipe, C_{exist} = 0.131ft; for a 0.75" pipe, C_{exist} = 0.196ft

[6] C = Diameter (in) * π/12.

For 0.75" pipe and 1/2" foam ((0.75 + 0.5 + 0.5) * π/12)

[7] Dropship is estimated higher than a free giveaway product as the building owner or contractor is required to actively order the required product online, confirm that it will be installed and EVT may inspect the installation at a later date. However since the installation is not performed by EVT staff or contractor (as in direct install), a 10% discount is applied.

[8] Assuming 3.5 feet each of both the hot and cold pipes.

[9] Navigant, "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", April 2009, page 77.

[10] Assuming R-3.2 (1/2" foam) pipe wrap insulation is added, as provided by the program. Please see attached specifications pdf or https://icf.amcgmarketplace.com/product/pipe-insulation/

[11] Review of AHRI database shows that Gas Residential Water Heaters (with Active AHRI certifications, Natural Gas, Fuel Oil & Propane Gas included) have an average recovery efficiency of 83%. Accessed February 2021.

[12] Measure lifetime from California DEER. Average of values for electric DHW (13 years) and gas DHW (11 years). See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[13] Program data provided list cost from vendor at $1.65 for a 7 ft section of pipe wrap. Rounded to $2 to account for labor & shipping costs.

[14] See file EVT Analysis file for calculation details.

Heat Pump Water Heater

Measure Number: RS-HWE-HPWH d
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Hot Water

Update Summary

Updated High Efficiency equipment standards to the latest NEEA "A Specification for Residential Water Heaters, Advanced Water Heating Specifications" Version 7.0, effective June 30, 2020. There has also been a shift in the Federal Baseline from measuring the Efficiency Rating as EF to UEF (Uniform Energy Factor). Values are comparable, with only a change to the rating's name. NEEA also renamed their Northern Climate Uniform Energy Factor (UEFnc) to Cool Climate Efficiency (CCE).

Also there was a program request to combine Tiers 1 & 2, whereas Tiers 3 & 4 remain seperate. As of December 2020, there are no Tier 2 Qualified products in the list tabulated by NEEA.

Referenced Documents

- NEEA HPWH Advanced-Water-Heating-Specification_7_0_FINAL
- NMR_VT SF Existing Homes Onsite Report - FINAL 072018
- ACSDPSY2018_DP04_2020-12-08
- Electronic Code of Federal Regulations eCFR_Title 10 Energy Chapter II D 430_32
- NEEA_AWHS HPWH-qualified-products-list_Updated 11_3_2020
- 1271697_44_41_-73_14_tmy-2019
- EPA_woodstoves_2020
- NEEP_ImprovedHPWaterHeaters_Incremental Costs_2016
- NEEP Incremental Cost Study FINAL_061016
- NREL_ National Residential Efficiency Measures Database - Retrofit Measures for Water Heater_HPWH 50 gal
- NREL_ National Residential Efficiency Measures Database - Retrofit Measures for Water Heater_HPWH 80 gal
- TRM_Analysis_RES HPWH_NEEA_Spec_2020 FINAL

Description

This measure charaterization provides documentation of prescriptive savings estimates for the installation of Heat Pump Water Heater (HPWH) in place of a baseline water heater in a residential application.

Savings are presented dependent on the existing water heater fuel type, Federal Standards, and HPWH storage volume. HPWH efficiency has been reduced to account for differences in field performance versus rated efficiency due to ambient conditions, hot water demand, and other factors, and a heating penalty is assessed to account for the impact of the HPWH on the home's heating load.

In program year 2017 Efficiency Vermont HPWH program adopted the NEEA Northern Climate Specification, which provides added energy efficiency guidance to manufacturers developing HPWHs. The updated equipment specification is known as the Advanced Water Heater Specification.

Homes with existing natural gas water heaters are not eligible for savings under this measure.

Program Type

Calculation Type: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Upstream, Downstream; Direct Install

Baseline Efficiencies

The baseline condition for a market opportunity HPWH is assumed to be a new water heater that uses the same fuel as the home's existing water heater and follows the current Federal Standard for residential water heaters[1]

High Efficiency

To qualify for this measure the installed equipment must be NEEA Tier 1, 2, 3 or 4 certified HPWH [2] .

Algorithms

Electric Demand Savings

The reduction (or increase) in electric demand due to the installation of a HPWH is derived below based on prescriptive energy savings found in **Table 3**.

ΔkW	= ΔkWh / Hours

Symbol Table

Electric Energy Savings

For cases where this measure is installed in a home with an existing electric resistance water heater, or in a new construction project, electric savings account for the improvement in performance of a HPWH over a baseline electric resistance water heater.

For homes with existing fossil fuel water heaters, the installation of a HPWH results in an electric penalty equal to the annual electricity use of the water heater to represent the added electric load.

In both scenarios, a penalty is taken into account for the heating load placed on a home's heating system by the HPWH, apportioned based on the percentage of homes in Vermont with electric heat.

For prescriptive purposes, savings and penalties will be assigned using *Deemed Values*, outlined in **Table 3**.

ΔkWh	$= \Delta UEF_{Elec} \times Q_{DHW} \times (1 - PF\_ElecHeat)$
ΔUEF_{Elec}	$= (1/UEF_{ElecBASE} - 1/UEF_{HPWh})$ *for homes with existing electric water heaters and new homes*
ΔUEF_{Elec}	$= - 1/UEF_{HPWh}$ *for homes with existing fossil fuel fired water heaters*
PF_ElecHeat	$= WHHF \times ExistDHWElec \times \%HeatSource_{Electric} / COP$

Symbol Table

Fossil Fuel Savings

For homes with existing fossil fuel water heaters, fuel switching results in fuel savings equal to the annual fuel use that would have resulted if a baseline fossil fuel fired water heater had been installed in the home.

For upstream measures where fossil fuel type may be unknown, savings are apportioned based on the breakdown of water heating fuels in Vermont homes, excluding natural gas. A fossil fuel penalty is taken to account for the heating load placed on a home's heating system by the HPWH.

For prescriptive purposes, this increased heating usage is allocated by fuel type based on the breakdown of primary heating fuel types in Vermont homes, excluding natural gas.

Savings and penalties will be assigned using deemed values, outlined in **Table 3**.

ΔMMBtu	= (SF_FF_DHW – PF_FF_Heating)
SF_FF_DHW	$= Q_{DHW} \times ExistDHWFF \times (((1/UEF_{PROPANE}) \times \%DHW_{PROPANE})+((1/UEF_{OIL}) \times \%DHW_{OIL}))$
PF_FF_Heating	$= WHHF \times ExistDHWElec \times \Delta UEF_{Elec} \times Q_{DHW} \times (((1/\eta Heat_{OIL}) \times \%HeatSource_{OIL})+((1/\eta Heat_{PROPANE}) \times \%HeatSource_{PROPANE}) +((1/\eta Heat_{WOOD}) \times \%HeatSource_{WOOD}))$

Symbol Table

Water Savings

Where:

%DHW$_{OIL}$	=	This factor apportions fuel oil savings for homes with unknown fuel types, a prescreening is conducted to exclude homes with existing natural gas water heaters.

Water Heater Fuel Source	%
Oil-fired	1.0
Unknown Fossil Fuel[11]	0.46
Propane-fired	0.0

%DHW$_{PROPANE}$	=	This factor apportions fuel oil savings for homes with unknown fuel types, a prescreening is conducted to exclude homes with existing natural gas water heaters.

Water Heater Fuel Source	%
Oil-fired	0.0
Unknown Fossil Fuel[11]	0.54
Propane-fired	1.0

%HeatSource = Portion of homes in Vermont with various heat sources. *Please see table below for values:*

Heating Fuel Type	Percentage of homes (VT)[3]
Electric	6.2%
Fuel Oil	53.4%
Propane	20.3%
Wood/Other	20.1%

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

ΔMMBtu = Gross customer annual MMBtu savings for the measure

ΔUEF$_{Elec}$ = Change in efficiency of water heating system

ηHeat = Weighted Average Efficiency, please see below for Fuel Types.

Fuel Oil[12]	Propane[12]	Wood[13]
82.8%	87.7%	73.0%

COP = Coefficient of Performance of electric space heating system

=2.52[4]

ExistDHWElec = 1 if the home has an existing electric water heater[5]

= −1 if the home has an existing fossil fuel fired water heater

ExistDHWFF = 1 if the home has an existing fossil fuel fired water heater

= 0 if the home has an existing electric water heater

Hours = Full load hours of water heater

= 2533

PF_ElecHeat = Heating penalty factor from conversion of electric heat in home to water heat.

PF_FF_Heating = Heating penalty factor from conversion of non-eletric heat in home to water heat.

Q$_{DHW}$ = Heat delivered to water in HPWH tank annually [6].

= 2,649 kWh[7]

= 9.04 MMBtu

SF_FF_DHW = Savings from fuel switching, accounts for replacement of baseline fossil fuel fired water heater by HPWH.

UEF$_{HPWh}$ = Uniform Energy Factor of heat pump water heater – prescriptive value based on NEEA Northern Climate Energy Factor, broken down by Tier & Volume capacity[8]

Please note, Efficiency Rating is either UEF or CCE depending on NEEA certificiation date. This is only a difference in name, not in calculation of tested value. There are currently no Tier 2 certified products on the NEEA QPL.

NEEA Tier	< 55 gallons	> 55 gallons
Tier 1 / Tier 2	2.33	2.41
Tier 3	2.95	3.10
Tier 4	3.15	3.20

UEF$_{ElecBASE}$ = Uniform Energy Factor of baseline electric water heater[1]

Fuel	Tank Volume	UEF
Electric	≥ 20 gal and ≤ 55 gal	0.92

UEF calculations assume Medium Draw pattern[9].

UEF$_{OIL}$ = Uniform Energy Factor (efficiency) of Baseline Fuel Oil water heater[1].

Fuel Type	Tank Volume	UEF
Oil	*All* [14]	0.53

UEF calculations assume Medium Draw pattern[9].

UEF$_{PROPANE}$ = Uniform Energy Factor (efficiency) of Baseline Propane water heater[1].

Fuel Type	Tank Volume	UEF
Propane	≥ 20 gal & ≤ 55 gal	0.56
Propane	>55 gal & ≤ 100 gal	0.76

UEF calculations assume Medium Draw pattern[9].

WHHF = Portion of reduced waste heat that results in increased heating

=0.542[10]

Mid-Life Savings Adjustment

N/A

Load Shapes

6a Residential DHW fuel switch

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
6	Residential DHW fuel switch	Active	40.2%	32.0%	15.1%	12.7%	40.1%	20.3%

Net Savings Factors

Measures

HWEHWHTP Heat Pump Water Heater

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032EPEP [is base track]	Efficient Products - Residential
6032UPST [6032EPEP]	Upstream - Residential
6013EPEP [6032EPEP]	Efficient Products - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	HWEHWHTP	1.00	1.00
Efficient Products - Residential	6032EPEP	HWEHWHTP	1.00	1.10

Lifetimes

The expected measure life is assumed to be 12 years[15]. For retrofit measures, it is assumed that the existing water heating equipment has four years of remaining life and would be replaced with baseline equipment with the associated installed cost at end of life. Analysis period is the same as the lifetime.

Measure Cost

For measures installed in a market opportunity situation, the measure cost is the incremental cost for the installation of a HPWH versus baseline equipment based on the existing water heater fuel type[16]. For retrofit measures, the measure cost is the full cost for the installation of a HPWH.

Table 1 – Measure Costs - Market Opportunity

HPWH Volume	*Existing DHW Energy Source*	*Incremental Cost*
< 55	Electric	$ 818
	Oil fired	
	Propane fired	
	Unknown Fossil Fuel	
> 55	Electric	$ 934[17]
	Oil fired	
	Propane fired	
	Unknown Fossil Fuel	

Table 2 – Measure Costs - Retrofit

HPWH Volume	*Full Cost of Installation* [18]
< 55	$ 2,087.41
> 55	$ 2,820.23[19]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Prescriptive Savings

For prescriptive purposes this measure has been binned based on Storage Volume range, existing water heater fuel type and proposed HPWH NEEA Tier as follows:

Table 3 – Prescriptive Savings Values[20]

Storage Volume	Existing DHW Fuel Source	NEEA Tier	ΔkWh	ΔkW	ΔMMBtu_Propane	ΔMMBtu_Oil	ΔMMBtu_Wood
< 55	Electric	Tier 1 / Tier 2	1,714.58	0.68	-0.74	-2.07	-0.88
		Tier 3	1,953.06	0.77	-0.85	-2.36	-1.01
		Tier 4	2,009.00	0.79	-0.87	-2.43	-1.04
	Fuel Oil	Tier 1 / Tier 2	-1,154.74	-0.46	-0.49	15.77	-0.58
		Tier 3	-909.76	-0.36	-0.38	16.06	-0.46
		Tier 4	-852.31	-0.34	-0.36	16.12	-0.43
	Propane	Tier 1 / Tier 2	-1,154.74	-0.46	15.56	-1.36	-0.58
		Tier 3	-909.76	-0.36	15.66	-1.07	-0.46
		Tier 4	-852.31	-0.34	15.69	-1.00	-0.43
	Unknown Fossil Fuel	Tier 1 / Tier 2	-1,154.74	-0.46	8.51	6.18	-0.58
		Tier 3	-909.76	-0.36	8.62	6.47	-0.46
		Tier 4	-852.31	-0.34	8.64	6.53	-0.43
> 55	Electric	Tier 1 / Tier 2	1,756.15	0.69	-0.76	-2.12	-0.91
		Tier 3	1,996.31	0.79	-0.87	-2.41	-1.03
		Tier 4	2,021.96	0.80	-0.88	-2.44	-1.04
	Fuel Oil	Tier 1 / Tier 2	-1,112.03	-0.44	-0.47	15.82	-0.56
		Tier 3	-865.34	-0.34	-0.37	16.11	-0.43
		Tier 4	-838.99	-0.33	-0.35	16.14	-0.42
	Propane	Tier 1 / Tier 2	-1,112.03	-0.44	11.35	-1.31	-0.56
		Tier 3	-865.34	-0.34	11.46	-1.02	-0.43
		Tier 4	-838.99	-0.33	11.47	-0.99	-0.42
	Unknown Fossil Fuel	Tier 1 / Tier 2	-1,112.03	-0.44	7.28	5.18	-0.56
		Tier 3	-865.34	-0.34	7.39	5.47	-0.43
		Tier 4	-838.99	-0.33	7.40	5.50	-0.42

Footnotes

[1] CFR, Title 10: Energy, Chapter II D §430.32(d) Energy and water conservation standards and their compliance dates. (Water Heaters). Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17. See sheet "Federal Std" in the Analysis File. Current link: http://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8

[2] NEEA Advanced Water Heater Specification v7.0 effective June 30, 2020. *See file "NEEA HPWH Advanced-Water-Heating-Specification_7_0_FINAL.pdf". Current link*: https://neea.org/our-work/advanced-water-heating-specification

[3] American Community Survey, 2014-2018 ACS 5Yr Data Profile, VT, Housing Characteristics Tables, excerpt from Table DP04. See sheet "ACS 5yr VT_2018" in Analysis file for a data summary or see file "ACSDP5Y2018.DP04_2020-12-08.csv" for the raw source data. (ACS 2018).

[4] The COP used is an assumption based upon baseline single head CCHP efficiencies, derived from an analysis of installed heat pumps in Vermont from Vermont heat pump distributors. Calculated from an HSPF of 8.6. Please review "EVT-CCHP-Efficiency Levels" sheet, copied data from Variable Speed Mini-Split Heat Pumps (Market Opportunity) measure analysis file.

[5] This factor ensures proper accounting of the heating penalty dependent on the fuel type of the home's existing water heater.

[6] UEF of Baseline water heater[7639] used in the calculations is 0.92 [8923].

[7] Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See sheet "Q_{DHW}" in Analysis file.

[8] NEEA Advanced Water Heater (Specification v7.0), Qualified Products List, accessed November 3, 2020. *See sheet "NEEA QPL 2020" in Analysis file for a data summary or see file* 'NEEA_AWHS HPWH-qualified-products-list_Updated 11.3.2020.pdf *" for the raw source data. Current link*: https://neea.org/our-work/advanced-water-heating-specification

[9] Volume used (Vr) based on average volume from NEEP Phase 3 Incremental Cost Study Data. See sheet "NEEP Raw Cost Data" in Analysis file for a data summary or see file "NEEP_ImprovedHPWaterHeaters_Incremental Costs_2016.xlsx" in the Installed Costs Table, for the raw source data. (NEEP 2016).

[10] Based on bin analysis of annual Heating Hours for Burlington, VT using the 2019 set of TMY3 data: 4747 / 8760 = 54.2%. Coordinates of data =

44.41 N, 73.14 W. Location comparable to Burlington Airport. *See sheet "TMY3_Heating Hours" in Analysis file for a data summary or see file "*1271697_44.41_-73.14_tmy-2019.csv*" for the raw source data.*

[11] Percentage Fossil Fuel split of "Homes heated in Vermont" was sourced from VT SF Existing Homes Onsite Report, Table 59, removing Natural Gas. (NMR Group, Inc. 2018)

[12] Weighted efficiencies based on VT SF Existing Homes Onsite Report Tables 46 & 47. (NMR Group, Inc. 2018)

[13] Weighted Average Efficiency was based off of EPA Compliant Models from Wood Stove Database, Room Heaters. *See sheet "EPA WoodStoves" in Analysis file for a data summary or see file "EPA_woodstoves_2020.xlsx" for the raw source data. Current link*: https://www.epa.gov/compliance/epa-certified-wood-heater-database (EPA Database accessed December 2020).

[14] Federal standard only provided for tank volume ≤ 50 gal. This calculated UEF was used for all sizes of fuel oil-fired tanks, as > 50 gallons is very rare.

[15] NREL, National Residential Efficiency Measure Database Lifetime of Heat Pump measures. Please see files in Referenced Documents. Current link: https://remdb.nrel.gov/measures.php?gId=6&ctId=270

[16] NEEP Emerging Technologies Incremental Cost Study Final Report, Table 3-34, pg 81. (2016). See sheet "NEEP Cost Summary" in the Analysis File. For Original Report see file "NEEP Incremental Cost Study FINAL_061016.pdf". Current link: http://www.neep.org/incremental-cost-emerging-technology-0.

[17] Average of Baseline Storage Water Heater for 60 & 80 (Gallons) categories in Market 1 Northern New England Incremental Cost ($/Unit).

[18] Full cost is based on average Installed cost from NEEP Phase 3 Incremental Cost Study Data. See sheet "NEEP Raw Cost Data" & realted pivot table in "Misc Calcs" of Analysis file for a data summary. For the raw data source, please see file "NEEP_ImprovedHPWaterHeaters_Incremental Costs_2016.xlsx", Installed Costs Table (NEEP 2016).

[19] Average Full Cost Heat Pump Water Heater for 60, 66 & 80 gallon capacity categories (NEEP 2016).

[20] See Analysis files for derivation of savings and input values. Prescriptive EF for each bin based on average EF of NEEA certified water heaters for each EF range.

Ducted Air Source Heat Pump (Market Opportunity)

Measure Number: CR-HVC-CDHPM a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

The updates to this measure include:

- Expanded the number of bins for this measure.
- Updated the analysis file with the most recent version of the NEEP Qualified Products List.
- Updated the EFLH to coincide with the updates to the ductless mini-split ASHP measure.
- Please note, these updates resulted in changes to the deemed savings.

Referenced Documents

- VT SF Existing Homes Onsite Report - DRAFT 122117
- New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs 2016
- Federal Efficienct Standards (CFR-2012-title10-vol3-sec430-32)
- GDS Associates_Measure Life Report_Jun 2007
- EVT_CCHP MOP and Retrofit_2018_
- 2015 VT Energy Code Handbook_V4.1
- EVT_Centrally Ducted ASHP_Analysis_Aug 2020_v2
- NEEP Air Source Heat Pump QPL_Aug 2020
- Mid-Atlantic_TRM_V9

Description

This measure claims savings for the installation of centrally ducted air source heat pumps. Heating and cooling savings are claimed as a market opportunity to account for the incremental savings of an efficient heat pump versus the installation of a less efficient baseline heat pump. The installed air source heat pump must meet Energy Star efficiency standards and have a capacity of <= 72,000 Btu/hr. The characterization assumes a standard mode of operation regardless of installation, location, or application - residential or commercial. The characterization of this measure assumes a midstream program delivery method.

Program Type

Calculation Type: Market Opportunity (Time of Sale)

Program Delivery/Implementation Method: Midstream

Baseline Efficiencies

The baseline condition is assumed to be a new heat pump that is capable of providing heat using the heat pump cycle and meets the following minimum efficiencies:

Table 1 - Residential Baseline Efficiency[1]

Equipment	HSPF	SEER
Air-Source Heat Pump	8.2	14

Table 2 - Commercial Baseline Efficiency[2]

Equipment	HSPF	SEER
Air-Source Heat Pump	8.1	14

Efficient Equipment

To qualify for savings under this measure, the installed equipment must be a centrally ducted air source heat pump listed on NEEP's Qualified Products List, COP at 5°F ≥ 1.75 (at maximum capacity operation), and be capable of providing heat using the heat pump cycle down to -5°F. It must also meet or exceed the following efficiency criteria, per AHRI Standard 210-240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump equipment.

Table 3 - Residential and Commercial High Efficiency[3]

Equipment	HSPF	SEER
Air-Source Heat Pump	10	15.6

Algorithms

Electric Demand Savings

$\Delta kW = kBtuh \times (1/HSPF_{Baseline} - 1/HSPF_{Efficient})$

Symbol Table

Electric Energy Savings

$\Delta kWh = kBtuh \times (1/HSPF_{Baseline} - 1/HSPF_{Efficient}) \times EFLH_{Heating} + tons \times (12/SEER_{Baseline} - 12/SEER_{Efficient}) \times EFLH_{Cooling}$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Total average summer coincident peak kW reduction (deemed assumption for prescriptive)
ΔkWh	=	Gross customer electric energy savings
$EFLH_{Cooling}$	=	Equivalent full load cooling hours 240 hours (residential)[5] 591 hours (commercial)[6]
$EFLH_{Heating}$	=	Equivlaent full load heating hours 1,383 hours (residential)[7] 1,062 hours (commercial)[6]
$HSPF_{Baseline}$	=	Heating Seasonal Performance Factor for Baseline equipment, Btu/Wh see table 1 and 2 (based on federal efficiency standards and VT CBES 2015)
$HSPF_{Efficient}$	=	Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh[8] see table 6 for more details
kBtuh	=	Average rated heating capacity[8] see table 6 for more details
$SEER_{Baseline}$	=	Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh see table 1 and 2 (based on federal efficiency standards and VT CBES 2015)
$SEER_{Efficient}$	=	Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh[9]

see table 6 for more details

Table 4 - Residential Savings Summary[4]

Average Cooling Capacity Bin	Capacity Range	Item Code	ΔkWh	ΔkW
9,000	<=10,500	RESASHPMOP09	228	0.13
12,000	>10,500 and <= 13,500	RESASHPMOP12	334	0.20
15,000	>13,500 and <= 16,500	RESASHPMOP15	378	0.23
18,000	>16,500 and <= 21,000	RESASHPMOP18	589	0.37
24,000	>21,000 and <= 27,000	RESASHPMOP24	629	0.37
30,000	>27,000 and <= 33,000	RESASHPMOP30	948	0.59
36,000	>33,000 and <= 39,000	RESASHPMOP36	1,263	0.80
42,000	>39,000 and <= 45,000	RESASHPMOP42	1,708	1.11
48,000	>45,000 and <= 51,000	RESASHPMOP48	2,288	1.52
54,000	>51,000 and <= 57,000	RESASHPMOP54	2,401	1.59
60,000	>57,000 and <= 63,000	RESASHPMOP60	2,901	1.91
66,000	>63,000 and <= 69,000	RESASHPMOP66	3,471	2.37
72,000	>69,000 and <= 72,000	RESASHPMOP72	3,946	2.71

Table 5 - Commercial Savings Summary[4]

Average Cooling Capacity Bin	Capacity Range	Item Code	ΔkWh	ΔkW
9,000	<=10,500	COMASHPMOP09	280	0.14
12,000	>10,500 and <= 13,500	COMASHPMOP12	376	0.21
15,000	>13,500 and <= 16,500	COMASHPMOP15	420	0.25
18,000	>16,500 and <= 21,000	COMASHPMOP18	601	0.40
24,000	>21,000 and <= 27,000	COMASHPMOP24	711	0.40
30,000	>27,000 and <= 33,000	COMASHPMOP30	988	0.64
36,000	>33,000 and <= 39,000	COMASHPMOP36	1,285	0.85
42,000	>39,000 and <= 45,000	COMASHPMOP42	1,680	1.17
48,000	>45,000 and <= 51,000	COMASHPMOP48	2,142	1.58
54,000	>51,000 and <= 57,000	COMASHPMOP54	2,271	1.66
60,000	>57,000 and <= 63,000	COMASHPMOP60	2,754	1.98
66,000	>63,000 and <= 69,000	COMASHPMOP66	3,100	2.46
72,000	>69,000 and <= 72,000	COMASHPMOP72	3,473	2.81

Table 6 - Deemed Values

Average Cooling Capacity Bin	Heating Capacity (kBtuh)	Average Cooling Capacity (tons)	$HSPF_{Efficient}$	$SEER_{Efficient}$
9,000	8.50	0.75	9.33	21.49
12,000	10.72	1.00	9.66	19.78
15,000	14.55	1.25	9.41	18.54
18,000	15.64	1.50	10.19	18.36
24,000	20.48	2.00	9.63	19.44
30,000	29.49	2.50	9.82	18.53
36,000	30.71	3.00	10.43	18.76
42,000	42.24	3.50	10.44	18.58
48,000	39.88	4.00	11.92	18.19
54,000	49.25	4.50	11.15	18.01
60,000	48.03	5.00	12.16	18.86
66,000	59.91	5.50	12.13	17.01
72,000	65.31	6.00	12.43	16.71

Load Shapes

116b Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
116	Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)	Active	40.8%	47.7%	6.2%	5.4%	36.9%	3.8%

Net Savings Factors

Measures

SHRDASHP	Centrally Ducted Air Source Heat Pump - Heat Pump Baseline

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032UPST [6032EPEP]	Upstream - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	SHRDASHP	1.00	1.00

Lifetimes

The expected measure life is assumed to be 18 years.[10]

Measure Cost

Table 7 - Residential and Commercial Measure Cost[11]

Measure cost represents the market opportunity incremental installed cost of an efficient versus a baseline air source heat pump.

Average Cooling Capacity Bin	Incremental Cost
9,000	$1,106
12,000	$1,140
15,000	$1,117
18,000	$1,288
24,000	$2,143
30,000	$2,230
36,000	$2,816
42,000	$3,160
48,000	$3,305
54,000	$3,551
60,000	$4,790
66,000	$3,259
72,000	$3,201

Footnotes

[1] The residential baseline efficiencies are sourced from the Federal Efficiency Standards as of 1/1/2015 for single and packaged central air

conditioners and heat pumps. Please find the ruling attached (Federal Efficient Standards (CFR-2012-title10-vol3-sec430-32)).

[2] The commercial baseline efficiency values are sourced from the VT CBES 2015 for the minimum efficiency requirements for electrically operated unitary and applied heat pumps.

[3] Cold climate air source heat pump, per NEEP's Qualified Products List, last updated on August 11, 2020. Please either find it attached ("NEEP Air Source Heat Pump QPL_Aug 2020.xlsx") or as the 'NEEP Product List' tab in the excel analysis file: "EVT_Centrally Ducted ASHP_Analysis_Aug 2020_v2.xlsx".

[4] Replacement scenario is defined as a MOP, so the baseline equipment is a less efficient heat pump meeting the minimum federal efficieny standards. Savings are being claimed on both the heating and cooling system. The peak demand savings for winter is being used as the primary demand savings. Please note that the NEEP Qualified Products List did not have centrally ducted air source heat pumps in the 66,000+ capacity bins, so instead of using actual equipment values for the 66,000 and 72,000 capacity bins, a trend analysis was performed based on the other bins in order to calculate prescriptive savings.

[5] Residential EFLH Cooling is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_2018_.xlsx.

[6] The commercial EFLH heating and cooling hours are sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

[7] Residential EFLH Heating is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating systems provide heating below 50°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of the baseline system at -5°F. The analysis assumes the heat pump provides heating based on its rated capacity (up to the estimated load) for each weather bin. EFLH is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_2018_.xlsx.

[8] The heating capacity and efficient heating HSPF is sourced from NEEP's Qualified Products List for centrally ducted heat pumps rated at varying temperatures (47°F, 17°F, and 5°F outdoor wet bulb temperature) and represent a weighted average BIN approach based on Burlington, VT weather data and capacities.

[9] The efficient cooling SEER and average cooling capacity is sourced from the NEEP Qualified Products List and represent a weighted average across all capacities

[10] "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.

[11] Mid-Atlantic Technical Reference Manual, version 9.0, October 2019 (Air Source Heat Pump, pg. 96). For more detail on the incremental cost estimates for the different measure bins, please see the 'Incremental Cost' tab in "EVT_Centrally Ducted ASHP_Analysis_Aug 2020_v2.xlsx".

Ducted Air Source Heat Pump (Retrofit)

Measure Number: CR-HVC-CDHPR a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

The updates to this measure include:

- Expanded the number of bins for this measure.
- Updated the analysis file with the most recent version of the NEEP Qualified Products List.
- Updated the EFLH to coincide with the updates to the ductless mini-split ASHP measure.
- Please note, these updates resulted in changes to the deemed savings.

Referenced Documents

- VT SF Existing Homes Onsite Report - DRAFT 122117
- New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs 2016
- GDS Associates_Measure Life Report_Jun 2007
- EVT_CCHP MOP and Retrofit_2018_
- EVT_Centrally Ducted ASHP_Analysis_Aug 2020_v2
- NEEP Air Source Heat Pump QPL_Aug 2020
- Mid-Atlantic_TRM_V9

Description

This measure claims savings for the installation of centrally ducted air source heat pumps. Heating savings are claimed as a retrofit of the home's existing fossil fuel heating system, and accounts for the fossil fuel system providing supplemental heat at low outdoor air temperatures. As only 2% of Vermont homes utilize central air conditioning[1], for this retrofit replacement scenario, the added electrical load associated with the heat pump is counted as a penalty for both heating and cooling. The installed air source heat pump must meet Energy Star efficiency standards and have a capacity of <= 72,000 Btu/hr. The characterization assumes a standard mode of operation regardless of installation, location, or application - residential or commercial. The installed air source heat pump is intended to supplement the existing fossil fuel heating system and not completely replace it, and the characterization of this measure assumes a midstream program delivery method.

This measure is in connection with the Market Opportunity characterization for centrally ducted air source heat pumps. As both characterizations, retrofit and market opportunity, will be implemented in tandem through an upstream delivery mechanism, the actual replacement scenario will be unknown and savings will be claimed for both measures to make sure they are additive and do not overlap.

Program Type

Calculation Type: Retrofit

Program Delivery/Implementation Method: Midstream

Baseline Efficiencies

The baseline condition is assumed to be the existing fossil fuel furnace. Sites with natural gas fossil fuel systems are excluded from participation in this measure and as a result, are not included in the characterization.

Table 1 - Residential Baseline Efficiency[2]

Existing Fuel Type	Average Furnace Efficiency
Fuel Oil	81.3%
Propane	87.4%

Table 2 - Commercial Baseline Efficiency[3]

Existing Fuel Type	Average Furnace Efficiency
Fuel Oil	82.0%
Propane	86.0%

Table 3 - Central Air Conditioning Baseline Efficiency

Sector	SEER
Residential[1]	11.4
Commercial[4]	11.7

Efficient Equipment

The installed heat pump is assumed to meet the efficiencies outlined in table 4.

Table 4 - Residential and Commercial High Efficiency

Equipment	HSPF	SEER
Residential Air-Source Heat Pump	8.2	14
Commercial Air-Source Heat Pump	8.1	14

Algorithms

Electric Demand Savings

$\Delta kW_{Penalty} = kBtuh \times (-1/HSPF_{Efficient})$

Symbol Table

Electric Energy Savings

$\Delta kWh_{Penalty} = kBtuh \times (-1/HSPF_{Efficient}) \times EFLH_{Heating} + \{(tons \times (12/SEER_{Baseline} - 12/SEER_{Efficient}) \times \%CAC) - (tons \times (12/SEER_{Efficient}) \times (1 - \%CAC))\} \times EFLH_{Cooling}$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu = (kBtuh \times EFLH_{Heating} / \eta_{Efficiency}) / 1000$

Where:

%CAC	=	Percent of existing homes in Vermont with central air conditioning = 2%[7]
$\Delta kW_{Penalty}$	=	Total average summer coincident peak kW penalty (deemed assumption for prescriptive)
$\Delta kWh_{Penalty}$	=	Gross customer electric energy penalty (deemed assumption for prescriptive)
ΔMMBtu	=	MMBtu savings for each fuel type (deemed assumption for prescriptive)
$\eta_{Efficiency}$	=	Efficiency of the fossil fuel heating system see tables 1 and 2 for more details
$EFLH_{Cooling}$	=	Equivalent full load cooling hours 240 hours (residential)[8] 591 hours (commercial)[9]

$EFLH_{Heating}$	=	Equivalent full load heating hours 1,383 hours (residential)[10] 1,062 hours (commercial)[9]
$HSPF_{Efficient}$	=	Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh see table 4 for more details
kBtuh	=	Average rated heating capacity[11] see table 8 for more details
$SEER_{Baseline}$	=	Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh see table 3 for more details
$SEER_{Efficient}$	=	Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh see table 4 for more details
tons	=	Average cooling capacity[12] see table 8 for more details

Table 5 - Furnace Type Distribution[5]

Fuel Type	Residential	Commercial
Fuel Oil	65.5%	37.8%
Propane	34.5%	62.2%

Table 6 - Residential Savings Summary[6]

Average Cooling Capacity Bin	Capacity Range	Item Code	ΔkWh	ΔkW	ΔMMBtu Oil	ΔMMBtu Propane
9,000	<=10,500	RESASHPRET09	-1,584	-1.037	9.5	4.6
12,000	>10,500 and <= 13,500	RESASHPRET12	-2,009	-1.308	12.0	5.9
15,000	>13,500 and <= 16,500	RESASHPRET15	-2,706	-1.775	16.2	7.9
18,000	>16,500 and <= 21,000	RESASHPRET18	-2,938	-1.907	17.4	8.5
24,000	>21,000 and <= 27,000	RESASHPRET24	-3,856	-2.498	22.8	11.2
30,000	>27,000 and <= 33,000	RESASHPRET30	-5,475	-3.596	32.9	16.1
36,000	>33,000 and <= 39,000	RESASHPRET36	-5,781	-3.745	34.2	16.8
42,000	>39,000 and <= 45,000	RESASHPRET42	-7,826	-5.151	47.1	23.0
48,000	>45,000 and <= 51,000	RESASHPRET48	-7,528	-4.863	44.4	21.8
54,000	>51,000 and <= 57,000	RESASHPRET54	-9,209	-6.006	54.9	26.9
60,000	>57,000 and <= 63,000	RESASHPRET60	-9,105	-5.858	53.5	26.2
66,000	>63,000 and <= 69,000	RESASHPRET66	-11,209	-7.307	66.8	32.7
72,000	>69,000 and <= 72,000	RESASHPRET72	-12,220	-7.965	72.8	35.6

Table 7 - Commercial Savings Summary[6]

Average Cooling Capacity Bin	Capacity Range	Item Code	ΔkWh	ΔkW	ΔMMBtu Oil	ΔMMBtu Propane
9,000	<=10,500	COMASHPRET09	-1,485	-1.050	4.2	6.5
12,000	>10,500 and <= 13,500	COMASHPRET12	-1,900	-1.324	5.3	8.2
15,000	>13,500 and <= 16,500	COMASHPRET15	-2,526	-1.797	7.1	11.2
18,000	>16,500 and <= 21,000	COMASHPRET18	-2,791	-1.930	7.7	12.0
24,000	>21,000 and <= 27,000	COMASHPRET24	-3,674	-2.529	10.0	15.7
30,000	>27,000 and <= 33,000	COMASHPRET30	-5,101	-3.640	14.4	22.6
36,000	>33,000 and <= 39,000	COMASHPRET36	-5,509	-3.791	15.0	23.6
42,000	>39,000 and <= 45,000	COMASHPRET42	-7,267	-5.214	20.7	32.4
48,000	>45,000 and <= 51,000	COMASHPRET48	-7,205	-4.923	19.5	30.6
54,000	>51,000 and <= 57,000	COMASHPRET54	-8,680	-6.080	24.1	37.8
60,000	>57,000 and <= 63,000	COMASHPRET60	-8,768	-5.930	23.5	36.9
66,000	>63,000 and <= 69,000	COMASHPRET66	-10,573	-7.397	29.4	46.0
72,000	>69,000 and <= 72,000	COMASHPRET72	-11,528	-8.063	32.0	50.1

Table 8 - Deemed Values

Average Cooling Capacity Bin	Heating Capacity (kBtuh)	Average Cooling Capacity (tons)
9,000	8.50	0.75
12,000	10.72	1.00
15,000	14.55	1.25
18,000	15.64	1.50
24,000	20.48	2.00
30,000	29.49	2.50
36,000	30.71	3.00
42,000	42.24	3.50
48,000	39.88	4.00
54,000	49.25	4.50
60,000	48.03	5.00
66,000	59.91	5.50
72,000	65.31	6.00

Load Shapes

123a Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
123	Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)	Active	41.6%	48.6%	5.2%	4.6%	36.9%	5.5%

Net Savings Factors

Measures

SHFDASHP	Centrally Ducted Air Source Heat Pump - Fuel-fired Baseline

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032UPST [6032EPEP]	Upstream - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	SHFDASHP	1.00	1.00

Lifetimes

The expected measure life is assumed to be 18 years.[13]

Measure Cost

Table 8 - Residential and Commercial Measure Cost[14]

The incremental retrofit cost is the full equipment cost of the air source heat pump.

Average Cooling Capacity Bin	Incremental Cost

9,000	$411
12,000	$548
15,000	$685
18,000	$823
24,000	$1,097
30,000	$1,371
36,000	$1,645
42,000	$1,919
48,000	$2,193
54,000	$2,468
60,000	$2,742
66,000	$3,016
72,000	$3,290

Footnotes

[1] "Vermont Single-Family Existing Homes Onsite Report", NMR Group, December 2017 (page 49)

[2] Average residential furnace efficiency of existing homes in Vermont, as sourced from homes surveyed in NMR Group's 2017 on site surveying; "Vermont Single-Family Existing Homes Onsite Report", NMR Groupt, December 2017 (page 45)

[3] Mean observed efficiency for warm air fossil fuel furnaces for existing commercial buildings, as sourced from "Vermont Market Assessment Report", Cadmus (page 65). The efficiency of propane furnaces was not included in the report. In order to incoporate the propane fuel type into the analysis, opted to use the combined efficiency values for propane boilers and furnaces, as sourced from the data for the same report.

[4] The baseline cooling efficiency for commercial central air conditioning systems is based on an aggregation of all cooling systems under 5.5 tons in commercial buildings, as sourced from the "Vermont Market Assessment Report", Cadmus, April 2017

[5] As the program delivery method for this measure is midstream, the intention is the fuel type of the furnace being off-set will be unknown, and this necissitates a fuel type distribution of furnaces being impacted by this measure. The MMBtu energy savings are thus split across the different fuel types based on their saturation in the state of Vermont and is dependant on the building stock and sector. Sites utilizing natural gas fuel are excluded from participating in this measure and are removed from consideration in this characterization. The derivation for the fuel type distribution and the accompanying sources can be viewed in detail in the "EVT_Centrally Ducted ASHP_Analysis_Aug 2020_v2.xlsx"

[6] Replacement scenario is defined as a RET, so the baseline equipment is the existing fossil fuel heating system (electric resistance heating was not considered a viable baseline for this measure). Fossil fuel savings are being claimed for the heating system with an electric penalty on both the heating and cooling sytem due to the installation of the heat pump. The peak demand savings for winter is being used as the primary demand savings. Please note that the NEEP Qualified Products List did not have centrally ducted air source heat pumps in the 66,000+ capacity bins, so instead of using actual equipment values for the 66,000 and 72,000 capacity bins, a trend analysis was performed based on the other bins in order to calculate prescriptive savings.

[7] 2% of Vermont single-family houses have central air conditionings, as sourced from the "VT SF Existing Homes Onsite Report", December 2017, NMR Group, page 49

[8] Residential EFLH Cooling is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_2018_.xlsx.

[9] The commercial EFLH heating and cooling hours are sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

[10] Residential EFLH Heating is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating systems provide heating below 50°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of the baseline system at -5°F. The analysis assumes the heat pump provides heating based on its rated capacity (up to the estimated load) for each weather bin. EFLH is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_2018_.xlsx.

[11] The heating capacity is sourced from NEEP's Qualified Products List for centrally ducted heat pumps rated at varying temperatures (47°F, 17°F, and 5°F outdoor wet bulb temperature) and represent a weighted average BIN approach based on Burlington, VT weather data and capacities.

[12] The average cooling capacity is sourced from the NEEP Qualified Products List and represent a weighted average across all capacities

[13] "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.

[14] Mid-Atlantic Technical Reference Manual, version 9.0, October 2019 (Air Source Heat Pump, pg. 96). For more detail on the incremental cost estimates for the different measure bins, please see the 'Incremental Cost' tab in "EVT_Centrally Ducted ASHP_Analysis_Aug 2020_v2.xlsx".

Ductless Air Source Heat Pump (Market Opportunity)

Measure Number: CR-HVC-DMHP c
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

Included the 40,000 Btu/h (32,001 - 48,000) and 56,500 Btu/h (48,001 - 65,000) capacity bins into the single zone measure per P&I staff request.

Please note, this TRM update was intended for only the expansion of capacity bins. This was done to align measure characterization with program implementation. While out-dated items were noted in the review of the measure, this will be taken into account when a comprehensive reliability review is performed on this measure later in the year. Those changes will be enacted for program year 2022, while these changes are intended to impact the measure for this year's program, 2021.

Referenced Documents

- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- DHP 116 MOP LoadProfileAverager_final
- VT existing homeowner survey report - DRAFT
- Existing Heating System Efficiency Analysis
- Upstream EVT CCHP Program Data_Cost Analysis
- Evaluation of Cold Climate Heat Pumps in Vermont
- EVT_CCHP_MOP and Retrofit_2021
- upstream-program-data-natural-gas-territory-research analysis

Description

This measure claims savings for the installation of single and multi-head variable speed mini-split heat pumps. Heating and cooling savings are claimed as a market opportunity to account for the incremental savings of an efficient heat pump versus the installation of a baseline heat pump. Given the use of heat pumps as a supplemental heating source, the characterization assumes a standard mode of operation regardless of installation location.

Program Type

Calculation Type: Market Opportunity (Time of Sale)

Program Delivery/Implementation Method: Midstream

Baseline Efficiencies

The baseline condition is assumed to be a new heat pump that is capable of providing heat using the heat pump cycle down to 5°F and meets the following minimum efficiencies:

Table 1 - Single Head Baseline Efficiency[1]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.6	9.8	15.6

Table 2 - Multi Head Baseline Efficiency[2]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.2	12	14.5

Efficient Equipment

To qualify for savings under this measure, the installed equipment must be a new mini-split heat pump that has a variable speed inverter-driven compressor, COP at 5°F ≥ 1.75 (at maximum capacity operation), and be capable of providing heat using the heat pump cycle down to -5°F. It must also meet or exceed the following efficiency criteria, per AHRI Standard 210-240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump equipment.

Table 3 - Single-Head High Efficiency[3]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	10	12	20

Table 4 - Multi-Head High Efficiency

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	10	12	17

Algorithms

Electric Demand Savings

Given the primary impact is on heating, demand impact is characterized for heating.

ΔkW	= (ΔkWh / EFLH) × New Construction Factor

Symbol Table

Electric Energy Savings

For the market opportunity measure, electric energy impacts are characterized as savings. Cooling impact uses full load cooling hours, and seasonal cooling efficiency. Heating impacts are characterized from EFLH derived from a metering analysis in the VT Heat Pump Evaluation.

ΔkWh	$= (\Delta kWh_{Cooling} + \Delta kWh_{Heating>=5F} - \Delta kWh_{Heating<5F}) \times$ New Construction Factor
$\Delta kWh_{Cooling}$	$= Q_{Cooling} \times EFLH_{Cooling} \times (1/SEER_{Baseline} - 1/SEER_{Efficient}) \times$ 1kWh/1000 Wh
$\Delta kWh_{Heating>5F}$	$= (\text{Max Capacity}_{5F}) \times EFLH \times (1/HSPF_{Baseline} \times 90\% - 1/HSPF_{Efficient} \times 90\%) \times$ 1 kWh/1000 Wh
$\Delta kWh_{Heating<5F}$	$= \Delta MMBtu \times (1/COP_{<5F} - \%ElecHeat) \times$ 1 kWh/ 3412 Btu

Where:

%ElecHeat	=	= portion of homes with electric space heat = 2%[5] (deemed assumption for prescriptive savings)
%HeatSource	=	= Percent of existing heating systems using fuel type *j*[9239] = 51% for fuel oil = 26% for propane = 4% for Wood = 11% for Natural Gas = 8% for Electric
ΔkW	=	Total average winter coincident peak kW reduction (deemed assumption for prescriptive)
$\Delta kWh_{Cooling}$	=	= Cooling Energy Savings

$\Delta kWh_{Heating>=5F}$	=	= Heating Energy Savings above 5°F
$\Delta kWh_{Heating<5F}$	=	= Heating Penalty below above 5°F
ΔkWh	=	= Gross customer electric energy savings
ΔMMBtu	=	MMBtu savings for each fuel type *j* (deemed assumption for prescriptive)
η_{Heatj}	=	= Heating system efficiency for fuel type *j* (deemed assumption for prescriptive)[9240] = 83% for fuel oil = 86% for propane = 66% for Wood/Other = 87% for Natural Gas =100% for Electric
90%	=	= Climatic adjustment to HSPF[6] (deemed assumption for prescriptive savings)
$COP_{<5F}$	=	= Assumed Coefficient of Performance below 5 degrees Fahrenheit =2.0[7]
$EFLH_{Cooling}$	=	= Equivalent Full Load Hours for heating = 239.81[8]
EFLH	=	Equivalent Full Load Hours for heating = 1,383[8]
$HSPF_{Baseline}$	=	= Heating Seasonal Performance Factor for Baseline equipment, Btu/Wh = 8.6[9](Single-head deemed assumption for prescriptive savings) = 8.2[10] (Multi-head deemed assumption for prescriptive savings)
$HSPF_{Efficient}$	=	= Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh
Max $Capacity_{5F}$	=	Average Maximum Capacity (Btu/hr) of the CCHP at 5 degrees Fahreneheit[11]
New Construction Factor	=	Factor to account for better thermal envelope of new construction homes = 99.25%[4]
$Q_{Cooling}$	=	= nominal cooling capacity, Btu/hr
$Q_{Heating<5F,i}$	=	= Maximum of rated heating capacity and estimated load in weather bin *i* below 5°F, MMBtu
$SEER_{Baseline}$	=	= Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh = 15.6[10](Single-head deemed assumption for prescriptive savings) = 14.5[10](Multi-head deemed assumption for prescriptive savings)
$SEER_{Efficient}$	=	= Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh

Load Shapes

116b Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
116	Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)	Active	40.8%	47.7%	6.2%	5.4%	36.9%	3.8%

Net Savings Factors

Measures

SHRHPCVH	Ductless single-head variable speed heat pump
SHRHPMHC	Ductless multi head variable speed heat pump

Tracks [Base Track]

6032UPST [6032EPEP]	Upstream - Residential
6013EPEP [6032EPEP]	Efficient Products - Commercial

Lifetimes

The expected measure life is assumed to be 15 years.[12]

Measure Cost

Single Head Measure Costs[13]

The incremental installed measure cost of an efficient versus a baseline CCHP:

Nominal Equipment Capacity (Btu/hr)	Incremental Costs
6,000	$483
9,000	$493
12,000	$591
15,000	$588
18,000	$611
24,000	$693
40,000	$881
56,500	$1,074

Multi-Head Measure Cost[13]

Measure cost represents the market opportunity incremental installed cost of an efficient versus a baseline multi head CCHP.

Nominal Equipment Capacity (Btu/hr)	Incremental Cost
18,000	$411
24,000	$265
30,000	$1,343
36,000	$603
42,000	$787
48,000	$736

Savings Summary

Type	Capacity	Capacity Ranges	Item Code	ΔkWh Total	ΔkW
Single Zone	6,000	5,000 - 8,000 BTU/h	CCHPSHEEC6K	612.3	0.41
Single Zone	9,000	8,001 - 11,000 BTU/h	CCHPSHEEC9K	619.1	0.41
Single Zone	12,000	11,001 - 14,000 BTU/h	CCHPSHEEC12K	607.9	0.40
Single Zone	15,000	14,001 - 17,000 BTU/h	CCHPSHEEC15K	872.5	0.58
Single Zone	18,000	17,001 - 22,000 BTU/h	CCHPSHEEC18K	680.3	0.44

Single Zone	24,000	22,001 - 32,000 BTU/h	CCHPSHEEC24K	792.6	0.51
Single Zone	40,000	32,001 - 48,000 BTU/h	CCHPSHEEC40K	1,102.0	0.70
Single Zone	56,500	48,001 - 65,000 BTU/h	CCHPSHEEC56K	1,482.1	0.93
Multi Zone	18,000	16,000 - 20,000 BTU/h	CCHPMHEEC18K	680.7	0.44
Multi Zone	24,000	20,001 - 24,000 BTU/h	CCHPMHEEC24K	1,160.6	0.77
Multi Zone	30,000	24,001 - 32,000 BTU/h	CCHPMHEEC30K	1,324.0	0.89
Multi Zone	36,000	32,001 - 38,000 BTU/h	CCHPMHEEC36K	1,759.3	1.17
Multi Zone	42,000	38,001 - 44,000 BTU/h	CCHPMHEEC42K	2,268.7	1.54
Multi Zone	48,000	44,001 - 65,000 BTU/h	CCHPMHEEC48K	1,791.0	1.16

Footnotes

[1] Baseline single head CCHP efficiencies is derived from an analysis of installed heat pumps in Vermont from Vermont heat pump distributors. Review Efficiency Levels tab in EVT_CCHP_MOP and Retrofit_2021.xlsx.

[2] Based on November 2014 TAG Agreement. Review of mutli-head CCHP shows HSPF average is below single-head units.

[3] High efficiencies for single and multi zone cold climate heat pumps are derived from various sources. HSPF rating based on NEEP criteria, refer to Cold Climate Air-source Heat Pump Specification-Version 2.0Jan2017 (1).pdf. EER rating based on ENERGY STAR specifications for air source heat pumps, refer to https://www.energystar.gov/products/heating_cooling/heat_pumps_air_source/key_product_criteria.

[4] See EVT_CCHP_MOP and Retrofit_2021.xlsx, New Construction tab for detailed analysis

[5] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Statewide Data). Kerosene, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump."

[6] Energy & Resource Solutions. (2014). *Emerging Technology Program Primary Research – Ductless Heat Pumps.* Lexington, MA: NEEP Regional EM&V Forum. Table 1-2. Page 5.

[7] Conservative average of low temperature COP according to manufacturer's engineering documents.

[8] EFLH is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP_MOP and Retrofit_2021.xlsx.

[9] Per TAG Agreement

[10] See Baseline Efficiency section

[11] This value is derived as an average of capacities that the CCHP can provide at 5 degrees Fahrenheit. These are from the engineering spec sheets of the CCHPs that are on the EVT QPL. For the 40,000 Btu/h and 56,500 Btu/h capacity bins, the values were interpolated from the previous bins.

[12] California DEER Effective Useful Life values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

[13] Navigant Consulting Inc. (2013). Incremental Cost Study Phase Two Final Report. Burlington, MA: NEEP Evaluation, Measurement, and Verification Forum. Review Costs tab of EVT_CCHP_MOP and Retrofit_2021.xlsx.

Variable Frequency Drives (VFD)

Measure Number: I-A-2 e
Portfolio: EVT TRM Portfolio 2019-04
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: HVAC

Update Summary

This update is the outcome of reliability review. The update reflected in this version is accomodation of new cost information. All other assumptions were found to have maintained reasonable validity and therefore were not revised.

Referenced Documents

- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- Efficiency Vermont 2016 VFD Loadshapes and Costs
- Cadmus. (2014). Variable Speed Drive Loadshape Project. Lexington: NEEP Regional Evaluation, Measurement and Verification Forum
- Incremental_Cost_Recommendations_Non_Lighting_050917
- VFD Costs

Description

This measure characterization presents standardized savings algorithms and assumptions for VFDs applied to motors of 100 HP or less for the following HVAC applications: supply fans, return fans, cooling water pumps, circulation pumps for water source heat pump systems, and heating hot water pumps ("Standardized Approach"). Standardized savings algorithms and assumptions of up to 10 HP for boiler draft fans and cooling tower fans are also applicable. All other VFDs are treated as custom measures.

The calculations for most of the applications rely heavily on a study conducted on behalf of the Northeast Energy Efficiency Partnerships (NEEP) Evaluation, Measurement, and Verification Forum (EM&V Forum), which conducts research studies to support energy-efficiency programs and policy in the Northeast and Mid-Atlantic states. In 2012, the EM&V Forum and its Sponsors commissioned this Variable Speed Drive (VSD) Loadshape study to determine the hourly energy and demand impacts of variable speed drives installed on HVAC equipment in existing nonresidential buildings throughout the Northeast and Mid-Atlantic.

Between 2013 and 2014, Cadmus and DMI (the evaluation team) worked with the EM&V Forum's Technical Committee to complete this study. The referenced report (Cadmus 2014) describes the study objective, methods, and results. The attached spreadsheet (NEEP 2016 provides more details on the data and the calculations.

Baseline Efficiencies

The baseline operation for supply fans, return fans, hot water pumps, cooling water pumps, and WSHP circulation pumps are described extensively in (Cadmus, 2014).[1] Sections 3.1, 3.2, and 3.3 of that document summarize how the baseline motors were being operated, while the methods of developing the baseline for modeling are described in detail in Section 2.4.4. The baseline includes a wide variety of operating conditions, including motors with continuous operation and very low (or no) operating hours, and both non-seasonal and seasonal systems. "Cooling water pumps" include both chilled water pumps and condenser water pumps. "Heating hot water pumps" refers to pumps that serve space heating loads, which may also serve DHW loads, as well as pumps that operate as hot water pumps for the heating season and cooling water pumps for the cooling season; it does not include DHW-only pumps.

For boiler draft fans, the baseline is assumed to be a draft fan with no VFD, while for cooling towers, the baseline reflects a tower fan with discharge damper controls.[2]

Efficient Equipment

The high efficiency case is installation and use of a VFD.

Algorithms

Electric Demand Savings

$\Delta kW = DSVG \times HP \times OTF$

Symbol Table

Electric Energy Savings

$\Delta kWh = ESVG \times HP \times OTF$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	gross kW connected load reductions for the measure, representing the average kW savings at either the summer or winter coincidence period (whichever is greater); see also Tables 4-6 below for prescriptive kW reduction values for each combination of horsepower and application
ΔkWh	=	gross customer annual kWh savings for the measure; see also Table 3 below for prescriptive kWh savings values for each combination of horsepower and application
DSVG	=	demand savings factor, calculated as the maximum of the summer and winter demand savings factors; see Table 1 below (kW/HP)
ESVG	=	energy savings factor; see Table 1 below (kWh/HP)
HP	=	horsepower of the motor to which the VFD is applied
kWh	=	gross customer annual kWh savings for the measure; see also Table 3 below for prescriptive kWh savings values for each combination of horsepower and application
OTF	=	operational testing factor for standard approach applications. OTF = 1.00 when the project undergoes operational testing or commissioning services, OTF = 0.9 otherwise. For prescriptive rebate form applications the OTF will be assumed to be 0.9.

Load Shapes

102a VFD - Boiler draft fans <10 HP
103a VFD - Cooling Tower Fans <10 HP
117a VFD WSHP Circulation Pumps - Prescriptive <=100 HP
55c VFD Supply Fans - Prescriptive <=100 HP
56c VFD Return Fans - Prescriptive <=100 HP
59c VFD Cooling Water Pumps - Prescriptive <=100 HP
76c VFD Heating Hot Water Pumps - Prescriptive <=100 HP

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
102	VFD - Boiler draft fans <10 HP	Active	45.8%	53.1%	0.7%	0.4%	40.0%	0.0%
103	VFD - Cooling Tower Fans <10 HP	Active	10.1%	5.0%	58.6%	26.3%	0.0%	61.6%
117	VFD WSHP Circulation Pumps - Prescriptive <=100 HP	Active	45.5%	23.1%	20.3%	11.1%	100.0%	77.1%
55	VFD Supply Fans - Prescriptive <=100 HP	Active	48.3%	18.5%	24.0%	9.2%	92.0%	100.0%
56	VFD Return Fans - Prescriptive <=100 HP	Active	53.6%	13.5%	26.2%	6.7%	90.7%	100.0%
59	VFD Cooling Water Pumps - Prescriptive <=100 HP	Active	45.5%	21.5%	22.2%	10.8%	100.0%	94.3%
76	VFD Heating Hot Water Pumps - Prescriptive <=100 HP	Active	35.8%	17.7%	8.0%	38.5%	100.0%	43.4%

Net Savings Factors

Measures

MTCSTVFD	Variable frequency drive, standardized
MTCVFDSF	VFD, standardized HVAC - Supply Fans
MTCVFDRF	VFD, standardized HVAC - Return Fans
MTCVFDCP	VFD, standardized HVAC - Cooling Water Pumps
MTCVFDHP	VFD, standardized HVAC - Heating Hot Water Pumps
MTCVFDBF	VFD, standardized HVAC - Boiler Draft Fans
MTCVFDWP	VFD, standardized HVAC - WSHP Circulation Pumps
MTCVFDCF	VFD, standardized HVAC - Cooling Tower Fans

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013PRES [is base track]	Pres Equip Rpl

Lifetimes

The measure life is assumed to be 15 years for HVAC applications.

Measure Cost

Because this is a retrofit measure, the cost is assumed to be the full installed cost of a VFD, and varies by controlled motor horsepower. See Table 2 "VFD Measure Costs" below.

Reference Tables

Table 1. Annual Energy and Demand Savings per Unit Horsepower Equipment Type[3]

	ESVG	DSVG[4]	$DSVG_{winter}$	$DSVG_{summer}$
	kWh/hp	kW/hp	kW/hp	kW/hp
Supply Fans	2,033	0.288	0.265	0.288
Return Fans	1,788	0.302	0.274	0.302
Cooling Water Pumps	1,633	0.194	0.194	0.183
Heating Hot Water Pumps	1,548	0.221	0.221	0.096
WSHP Circulation Pumps	2,562	0.297	0.297	0.229
Boiler Draft Fans	500	0.270	0.108	0.0
Cooling Tower Fans	239	0.280	0.0	0.17248

Table 2. Variable Frequency Drive (VFD) Costs[5]

Horsepower	Labor	Equip/Materials	Total Installation Cost
2	$456.08	$1,558.20	$2,014.27
3	$472.03	$1,619.02	$2,091.05
5	$503.94	$1,740.67	$2,244.61
7.5	$543.83	$1,842.31	$2,386.14
10	$583.71	$1,943.95	$2,527.66
15	$830.89	$2,898.95	$3,729.84
20	$912.50	$3,189.44	$4,101.94
25	$994.12	$3,479.93	$4,474.05
30	$1,075.73	$3,770.42	$4,846.15
40	$1,238.96	$4,351.39	$5,590.36
50	$1,402.19	$4,932.37	$6,334.56
60	$1,895.35	$5,513.35	$7,408.70
75	$1,959.51	$6,384.81	$8,344.32
100	$2,066.43	$7,837.26	$9,903.68

Table 3. Prescriptive Energy Savings (kWh)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	3,659.4	3,218.4	2,939.4	2,786.4	4,611.6	900.0	430.2
3	5,489.1	4,827.6	4,409.1	4,179.6	6,917.4	1,350.0	645.3
5	9,148.5	8,046.0	7,348.5	6,966.0	11,529.0	2,250.0	1,075.5
7.5	13,722.8	12,069.0	11,022.8	10,449.0	17,293.5	3,375.0	1,613.3
10	18,297.0	16,092.0	14,697.0	13,932.0	23,058.0	4,500.0	2,151.0
15	27,445.5	24,138.0	22,045.5	20,898.0	34,587.0	NA	NA
20	36,594.0	32,184.0	29,394.0	27,864.0	46,116.0	NA	NA
25	45,742.5	40,230.0	36,742.5	34,830.0	57,645.0	NA	NA
30	54,891.0	48,276.0	44,091.0	41,796.0	69,174.0	NA	NA
40	73,188.0	64,368.0	58,788.0	55,728.0	92,232.0	NA	NA
50	91,485.0	80,460.0	73,485.0	69,660.0	115,290.0	NA	NA
60	109,782.0	96,552.0	88,182.0	83,592.0	138,348.0	NA	NA
75	137,227.5	120,690.0	110,227.5	104,490.0	172,935.0	NA	NA
100	182,970.0	160,920.0	146,970.0	139,320.0	230,580.0	NA	NA

Table 4. Prescriptive Connected Load Reduction (kW)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	0.51840	0.54360	0.34920	0.39780	0.53460	0.48600	0.50400
3	0.77760	0.81540	0.52380	0.59670	0.80190	0.72900	0.75600
5	1.29600	1.35900	0.87300	0.99450	1.33650	1.21500	1.26000
7.5	1.94400	2.03850	1.30950	1.49175	2.00475	1.82250	1.89000
10	2.59200	2.71800	1.74600	1.98900	2.67300	2.43000	2.52000
15	3.88800	4.07700	2.61900	2.98350	4.00950	NA	NA
20	5.18400	5.43600	3.49200	3.97800	5.34600	NA	NA
25	6.48000	6.79500	4.36500	4.97250	6.68250	NA	NA
30	7.77600	8.15400	5.23800	5.96700	8.01900	NA	NA
40	10.36800	10.87200	6.98400	7.95600	10.69200	NA	NA
50	12.96000	13.59000	8.73000	9.94500	13.36500	NA	NA

60	15.55200	16.30800	10.47600	11.93400	16.03800	NA	NA
75	19.44000	20.38500	13.09500	14.91750	20.04750	NA	NA
100	25.92000	27.18000	17.46000	19.89000	26.73000	NA	NA

Table 5. Prescriptive Winter Coincident Demand Reduction (kW)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	0.47700	0.49320	0.34920	0.39780	0.53460	0.19440	0.00
3	0.71550	0.73980	0.52380	0.59670	0.80190	0.29160	0.00
5	1.19250	1.23300	0.87300	0.99450	1.33650	0.48600	0.00
7.5	1.78875	1.84950	1.30950	1.49175	2.00475	0.72900	0.00
10	2.38500	2.46600	1.74600	1.98900	2.67300	0.97200	0.00
15	3.57750	3.69900	2.61900	2.98350	4.00950	NA	NA
20	4.77000	4.93200	3.49200	3.97800	5.34600	NA	NA
25	5.96250	6.16500	4.36500	4.97250	6.68250	NA	NA
30	7.15500	7.39800	5.23800	5.96700	8.01900	NA	NA
40	9.54000	9.86400	6.98400	7.95600	10.69200	NA	NA
50	11.92500	12.33000	8.73000	9.94500	13.36500	NA	NA
60	14.31000	14.79600	10.47600	11.93400	16.03800	NA	NA
75	17.88750	18.49500	13.09500	14.91750	20.04750	NA	NA
100	23.85000	24.66000	17.46000	19.89000	26.73000	NA	NA

Table 6. Prescriptive Summer Coincident Demand Reduction (kW)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	0.51840	0.54360	0.32940	0.17280	0.41220	0.00	0.31046
3	0.77760	0.81540	0.49410	0.25920	0.61830	0.00	0.46570
5	1.29600	1.35900	0.82350	0.43200	1.03050	0.00	0.77616
7.5	1.94400	2.03850	1.23525	0.64800	1.54575	0.00	1.16424
10	2.59200	2.71800	1.64700	0.86400	2.06100	0.00	1.55232
15	3.88800	4.07700	2.47050	1.29600	3.09150	NA	NA
20	5.18400	5.43600	3.29400	1.72800	4.12200	NA	NA
25	6.48000	6.79500	4.11750	2.16000	5.15250	NA	NA
30	7.77600	8.15400	4.94100	2.59200	6.18300	NA	NA
40	10.36800	10.87200	6.58800	3.45600	8.24400	NA	NA
50	12.96000	13.59000	8.23500	4.32000	10.30500	NA	NA
60	15.55200	16.30800	9.88200	5.18400	12.36600	NA	NA
75	19.44000	20.38500	12.35250	6.48000	15.45750	NA	NA
100	25.92000	27.18000	16.47000	8.64000	20.61000	NA	NA

Table 7. ItemCode Mapping

Note: "NA" entries indicate product combination is not offered in the EVT presriptive program.

Horsepower	**Supply Fans**	**Return Fans**	**Cooling Water Pumps**	**Heating Hot Water Pumps**	**WSHP Circulation Pumps**	**Boiler Draft Fans**	**Cooling Tower Fans**
2	VT-VFDSUPFAN2	VT-VFDRETFAN2	NA	NA	NA	VT-VFDBDRFAN2	VT-VFDCTRFAN2
3	VT-VFDSUPFAN3	VT-VFDRETFAN3	VT-VFDCHWPMP3	VT-VFDBDPMP3	VT-VFDWSHPPMP3	VT-VFDBDRFAN3	VT-VFDCTRFAN3
5	VT-VFDSUPFAN5	VT-VFDRETFAN5	VT-VFDCHWPMP5	VT-VFDBDPMP5	VT-VFDWSHPPMP5	VT-VFDBDRFAN5	VT-VFDCTRFAN5
8	VT-VFDSUPFAN7.5	VT-VFDRETFAN7.5	VT-VFDCHWPMP7.5	VT-VFDBDPMP7.5	VT-VFDWSHPPMP7.5	VT-VFDBDRFAN7.5	VT-VFDCTRFAN7.5
10	VT-VFDSUPFAN10	VT-VFDRETFAN10	VT-VFDCHWPMP10	VT-VFDBDPMP10	VT-VFDWSHPPMP10	VT-VFDBDRFAN10	VT-VFDCTRFAN10
15	VT-VFDSUPFAN15	VT-VFDRETFAN15	VT-VFDCHWPMP15	VT-VFDBDPMP15	VT-VFDWSHPPMP15	NA	NA
20	VT-VFDSUPFAN20	VT-VFDRETFAN20	VT-VFDCHWPMP20	VT-VFDBDPMP20	VT-VFDWSHPPMP20	NA	NA
25	VT-VFDSUPFAN25	VT-VFDRETFAN25	VT-VFDCHWPMP25	VT-VFDBDPMP25	VT-VFDWSHPPMP25	NA	NA
30	VT-VFDSUPFAN30	VT-VFDRETFAN30	VT-VFDCHWPMP30	VT-VFDBDPMP30	VT-VFDWSHPPMP30	NA	NA
40	VT-VFDSUPFAN40	VT-VFDRETFAN40	VT-VFDCHWPMP40	VT-VFDBDPMP40	VT-VFDWSHPPMP40	NA	NA
50	VT-VFDSUPFAN50	VT-VFDRETFAN50	VT-VFDCHWPMP50	VT-VFDBDPMP50	VT-VFDWSHPPMP50	NA	NA
60	VT-VFDSUPFAN60	VT-VFDRETFAN60	VT-VFDCHWPMP60	VT-VFDBDPMP60	VT-VFDWSHPPMP60	NA	NA
75	VT-VFDSUPFAN75	VT-VFDRETFAN75	VT-VFDCHWPMP75	VT-VFDBDPMP75	VT-VFDWSHPPMP75	NA	NA
100	VT-VFDSUPFAN100	VT-VFDRETFAN100	VT-VFDCHWPMP100	VT-VFDBDPMP100	VT-VFDWSHPPMP100	NA	NA

Footnotes

[1] (Cadmus, 2014), Sections 2.4.4 Hourly Baseline Operating Power (pp. 38-43); 3.1 Final Study Sample (p.51); 3.2 Observations on VSD Operation (pp. 51-55); 3.3 Pre-Retrofit Operation (pp. 55-57).

[2] (Efficiency Vermont, 2011), Overview; Summary.

[3] Savings factors for Supply Fans, Return Fans, Cooling Water Pumps, Heating Hot Water Pumps, and WSHP Circulation Pumps from (Cadmus, 2014), Table 6 Annual Energy Savings per Unit Horsepower (p. xiv) and Table 7 ISO-NE Summer and Winter On-Peak Demand Savings per Unit Horsepower (p. xiv). Savings factors for Boiler Draft Fans and Cooling Tower Fans from (Efficiency Vermont, 2011), Summary worksheet. The Efficiency Vermont savings analysis is based on Equest modeling performed by Efficiency Vermont. For boiler draft fans the factors are based on an analysis of office applications, while for cooling tower fans the factors are based on an average of the results of analyses for office and school applications.

[4] The DSVG represents the maximum of the summer and winter demand savings factors identified in the source analyses. The summer and winter DSVG may be derived by multiplying the DSVG by the respective coincidence factors from the designated loadshapes for each application.

[5] Equipment and labor costs from the Mid-Atlantic Tenchincal Reference Manual Version 8, adjusted to the Northern New England region per the methodology set forth in the Navigant Consulting, 2013 Incremental Cost Study Phase Two Final Report (see Referenced Documents). Cost derivation is shown in Referenced Document titled "VFD Costs.xlsx." Original data source for the Mid-Atlantic TRM Version 8 costs is the Referenced Document tited "Incremental_Cost_Recommendations_Non_Lighting_050917."

Commercial Brushless Permanent Magnet (BLPM) Fan Motor

Measure Number: I-A-6 c
Portfolio: 94
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: HVAC

Update Summary

Updates to the measure include the following:

- All references were determined to be out-of-date and have been updated with more recent studies, resources, and savings spreadsheets.
- Energy/Demand Algorithms have been updated to include a bonus factor to account for additional kWh savings for cooling due to less heat loss of efficient fans.
- Deemed values and savings calculations have been updated to reflect updated references.

Referenced Documents

- Commercial Furnace Fan Motor Savings
- Navigant, "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", 2013.
- DEER2014-EUL-table-update_2014-02-05.xlsx
- Commercial BLPM Fan Motor Savings.xlsx
- NREL, "Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014.
- NEEP HVAC Load Shape Report_ Final_August2
- New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016

Description

This measure will provide incentives for installing an ultra high efficiency programmable brushless permanent magnet fan motor called Brushless Permanent Magnet Motor (BLPM, sometimes referred to as ECM, ICM, or brushless DC motor), hereafter referred to as "BLPM fan motor." The incentive offer and savings estimation relate only to the efficiency gains associated with an upgrade to a BLPM fan motor, rather than for improvements in the efficiency of the heating and cooling equipment. That is, increases in AFUE or EER/SEER are NOT covered by this measure. The installation of a BLPM fan motor for businesses can apply to: just the heating system (heating only), just the central A/C system (cooling only), or for an air handler servings both heating and cooling systems (heating and cooling).

Estimated Measure Impacts

Algorithms

Demand Savings

$\Delta kW = ((Watts_{Base} - Watts_{EE}) / 1000) \times BF$

Symbol Table

Energy Savings

$\Delta kWh = ((Watts_{Base} - Watts_{EE}) / 1000) \times (Hours_{Heating} + Hours_{Cooling} \times BF)$

Where:

ΔkW	=	Maximum customer kW savings
ΔkWh	=	Gross customer annual kWh savings
1000	=	Convert watts to kilowatts
BF	=	Bonus Factor to account for reduced waste heat of baseline motor. 1.3 for Cooling; 1.0 for Heating Only applications.[1]
$Hours_{Cooling}$	=	Hours of fan operation for Cooling application. 755 hours[4]; Cooling hours are 0 for Heating Only applications
$Hours_{Heating}$	=	Hours of fan operation for Heating application. 1238 hours[5]; Heating hours are 0 for Cooling Only applications.
$Watts_{Base}$	=	Power consumption of baseline fan motor. 571 Watts.[2]
$Watts_{EE}$	=	Power consumption of energy efficient fan motor. 392 Watts.[3]

Average Savings for BLPM Commercial HVAC Fan Motors

Application	kWh savings	kW savings
Heating Only	222	0.179
Cooling Only	181	0.240
Heating and Cooling	403	0.240

Baseline Efficiencies

A low-efficiency permanent split capacitor (PSC) fan motor on a hot air furnace, split system air conditioner, or a combined air handling system serving both heating and cooling.

High Efficiency

A brushless permanent magnet motor (BLPM, also called ECM, ICM, and other terms) on a hot air furnace, split system air conditioner, or a combined air handling system serving both heating and cooling.

Operating Hours

Heating: 1238 hours/year.[5]

Cooling: 755 hours/year.[4]

Load Shapes

See derivation of the savings profiles in "Commercial Furnace Fan Motor Savings.xls".

78c BLPM Fan Motor Commercial Heating
79c BLPM Fan Motor Commercial Cooling
80c BLPM Fan Motor Commercial Heating & Cooling

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
78	BLPM Fan Motor Commercial Heating	Active	34.4%	56.1%	4.5%	5.0%	50.2%	19.0%
79	BLPM Fan Motor Commercial Cooling	Active	18.3%	0.4%	67.4%	13.9%	0.0%	80.1%

80	BLPM Fan Motor Commercial Heating & Cooling	Active	30.9%	42.2%	19.1%	7.8%	50.2%	52.4%

Net Savings Factors

Measures

SHEFNMTR	Furnace fan motor

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl
6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	SHEFNMTR	1.00	1.00
Cust Equip Rpl	6013CUST	SHEFNMTR	1.00	1.00
Pres Equip Rpl	6013PRES	SHEFNMTR	1.00	1.00
LIMF NC	6018LINC	SHEFNMTR	1.00	1.00
MF Mkt NC	6019MFNC	SHEFNMTR	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years.[6]

Measure Cost

$180 for Market Opportunity[7]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There is an increase in fossil fuel use associated with this measure, due to the decrease in waste heat produced by the BLPM motor during the heating season.

ΔMMBtu = 0.5[8] for Heating Only, as well as Heating and Cooling

ΔMMBtu = 0.0 for Cooling Only

Incentive Level

Footnotes

[1] Bonus Factors derived from the difference in total savings of the efficient motor and the calculated savings based on motor demands and operating hours. NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Page 18, Table 8. For bonus factor calculation see reference file “Commercial BLPM Fan Motor Savings.xls”.

[2] Average baseline motor demand derived from results of NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Page 12, Tables 3 and 4. For calculation see reference file “Commercial BLPM Fan Motor Savings.xlsx”.

[3] Average efficient motor demand derived from results of NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Page 12, Tables 3 and 4. For calculation see reference file “Commercial BLPM Fan Motor Savings.xlsx”.

[4] EFLH for commercial air conditioning are derived directly from the following KEMA report. KEMA, "C&I Unitary HVAC Load Shape Project Final Report", Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, August 2, 2011. Pg. 57, Table 3-1.

[5] Equivalent full load heating hours were derived from New York reported EFLH for small commercial heating applications. Hours were adjusted using TMY3 data for Vermont and New York. See reference file “Commercial BLPM Fan Motor Savings.xlsx”, ‘EFLH_Heating’ Tab. New York EFLH hours are referenced from New York State Joint Utilities, "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", Version 4, April 2016. Pg. 444, Appendix G - Small Commercial Heating EFLH.

[6] Effective Useful Life as determined in the 2014 update of the DEER Database. See reference file “DEER 2014 EUL Table Update.xlsx”

[7] Costs are based on the market opportunity of a BLPM motor on a new furnace. Navigant Consulting, “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment”, 2013. Page 28, Table 3.6.

[8] See calculation in “Commercial BLPM Fan Motor Savings.xls,” based on waste heat reduction of fan motor resulting in an increase in heating load. Results from NREL study were adjusted based on Vermont operating hours. NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Pages 16-17, Tables 6-7.

Brushless Permanent Magnet (BLPM) Circulator Pump

Measure Number: I-A-7 b
Portfolio: 96
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: HVAC

Update Summary

- The measure has been updated to replace a list of manufacturer pump data with more recent circulator pump studies and pump motor efficiency data

Referenced Documents

- Navigant, "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", 2013.
- Commercial BLPM Pump Motor Analysis.xlsx
- EPRI, "Assessment of New Energy Efficient Circulator Pump Technology", 2010.
- EPRI, "Assessment of New Motor Technologies and their Applications", 2013.

Description

This measure is for installing circulator pumps with brushless permanent magnet pump (BLPM) motors, less than or equal to three horsepower. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in multifamily residences and small commercial buildings. This measure is restricted to systems that use high mass boilers (>300,000 Btu/h) where the primary loop circulator runs constantly during the heating season. Circulator pumps that use BLPMs are more efficient because they lack brushes that add friction to the motor, as well as the ability to modulate their speed to match the load. This is possible because the drive senses the difference between the magnetic field of the rotating rotor and the rotating magnetic field of the windings in the motor stator. As the system flow demand changes (zones open or close), the drive senses the torque difference at the impeller via the change in the magnetic field difference and adjusts its speed by altering the frequency to the motor. BLPMs are especially efficient in no-load/low-load applications.

Baseline Efficiencies

The baseline equipment is a circulator pump using a low-efficiency induction motor. It is assumed that this pump is installed on the primary loop of a multi-loop system, and is running constantly when outside temperatures are 55°F or lower during the winter heating season (October – April).

Efficient Equipment

The efficient equipment is a circulator pump with brushless permanent magnet motor.

Algorithms

Electric Demand Savings

ΔkW	$= (Watts_{Base} - Watts_{Eff}) / 1000$

Demand Savings for Commercial BLPM Pump Motors[1]

Where W_{MAX} = Maximum rated wattage of efficient circulator pump (nameplate information)

Maximum Rated Watts (BLPM Motor)	Average Rated Watts for BLPM Pump Motor[2]	Average Watts for Baseline Pump Motor[3]	Average Demand Savings ΔkW
$W_{MAX} \leq 144$	74	141	0.0675
$144 < W_{MAX} \leq 575$	276	371	0.0953
$575 < W_{MAX} \leq 2500$	1082	1209	0.1270

Symbol Table

Electric Energy Savings

ΔkWh	$= (Watts_{Base} - Watts_{Eff} \times (1 - Control)) / 1000 \times Hours$

Energy Savings for Commercial BLPM Pump Motors[1]

Where W_{MAX} = Maximum rated wattage of efficient circulator pump (nameplate information)

Maximum Rated Watts (BLPM Motor)	Average Annual Energy Savings ΔkWh
$W_{MAX} \leq 144$	401.3
$144 < W_{MAX} \leq 575$	780.1
$575 < W_{MAX} \leq 2500$	1924.3

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW). Savings calculated by different bins of efficient wattages
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
1000	=	Conversion from watts to kilowatts
Control	=	Control factor accounts for additional savings due to reduced power operation and control functions utilized with BLPM pump motor; 0.27.[4]
Hours	=	Annual operating hours during heating season; 4592 hours.[5]
$Watts_{Base}$	=	Watt rating of baseline induction motor. Baseline rating is estimated based on rating of efficient motor replacement
$Watts_{Eff}$	=	Maximum Watt rating of efficient BLPM motor. Refer to Demand Savings table below for motor size bins

Operating Hours

The annual operating hours are assumed to be 4592[5]

Load Shapes

17b Commercial Space Heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
17	Commercial Space Heat	Active	43.2%	52.3%	1.6%	3.0%	17.9%	0.6%

Net Savings Factors

Measures

SHECPMTR	Brushless Permanent Magnet (BLPM) Circulator Pump

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	SHECPMTR	0.95	1.00

Persistence

The persistence factor is assumed to be 1.

Lifetimes

20 years – typical circulator pumps using low-efficiency induction motors are expected to last around 15 years; circulator pump motors with BLPMs typically operate at lower RPMs, thus producing less heat and extending the life of the motor.

Measure Cost

The estimated full cost for this measure varies based on the size of the motor. See the table below for further details.

Cost for Commercial BLPM Pump Motors[6]

Where W_{MAX} = Maximum rated wattage of efficient circulator pump (nameplate information)

Maximum Rated Watts (BLPM Motor)	Average Cost (incl. Labor)
$W_{MAX} \leq 144$	$547
$144 < W_{MAX} \leq 575$	$1,643
$575 < W_{MAX} \leq 2500$	$3,316

O&M Cost Adjustments

None.

Water Descriptions

None.

Footnotes

[1] For pump savings analysis see reference file "Commercial BLPM Pump Motor Analysis.xlsx"

[2] Average wattages determined from list of EVT qualified pump models as of December 2016. For details see reference file "Commercial BLPM Pump Motor Analysis.xlsx".

[3] Average baseline wattages are calculated using motor efficiency curves and the average wattages of efficient BLPM motors. For calculations see reference file "Commercial BLPM Pump Motor Analysis.xlsx". Efficiencies developed from the following sources. U.S. DOE, "Premium Efficiency Motor Selection and Application Guide", 2014; Navigant, "Energy Saving Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment" provided to the U.S. DOE, 2013.

[4] The control factor is derived using motor efficiency curves and the results of the following EPRI studies to account for additional savings from operating control modes of efficient BLPM motors; EPRI, "Assessment of New Motor Technologies and their Applications", 2013. EPRI, "Assessment of New Energy Efficient Circulator Pump Technology", 2010. For details see reference file "Commercial BLPM Pump Motor Analysis.xlsx".

[5] Operating hours are calculated as the total hours between the months of October 1st and April 30th where the outside air dry-bulb temperature is below 55°. Hours are an average number of heating season hours from 2012 through 2015. See reference file "Commercial BLPM Pump Motor Analysis.xlsx".

[6] For costs analysis see reference file "Commercial BLPM Pump Motor Analysis.xlsx"

Commercial Ventilation Fan

Measure Number: I-B-5 b
Portfolio: EVT TRM Portfolio 2017-07
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: HVAC

Update Summary

This is a reliability update that includes a change of high efficiency levels (CFM/watt) based on custom projects that have been performed over the past 4 years. This analysis follows the previous methodology, which reveiwed custom projects from 2009-2012.

Referenced Documents

- measure_life_GDS[1]
- evt-commercial-ventilation-fan-analysis-july-2017-xlsx

Description

An ENERGY STAR qualified efficient fan configured to meet ASHRAE 62.1 requirements for bathroom ventilation. This market opportunity is defined by the need for continuous mechanical ventilation in bathrooms and mechanical closets of small commercial and industrial buildings during operating hours. This measure assumes an efficient fan will be run during business hours to provide 10-500 CFM under static pressure conditions ranging from 0.1 to 0.25 inches of water.

Algorithms

Electric Demand Savings

$\Delta kW = CFM \times (1 / Fan_{Efficiency, Baseline} - 1 / Fan_{Efficiency, Efficient}) / 1000$

Symbol Table

Electric Energy Savings

$\Delta kWh = Hours \times \Delta kW$

Where:

ΔkW = connected load kW savings per qualified ventilation fan and controls

Demand Savings

CFM code	Nominal CFM Range	Assumed CFM	ΔkW
CFM1	10-89	70	0.029
CFM2	90-150	110	0.046
CFM3	151-250	175	0.073
CFM4	251-500	350	0.145

ΔkWh = Energy Savings

CFM code	Nominal CFM Range	Assumed CFM	ΔkWh
CFM1	10-89	70	85
CFM2	90-150	110	133
CFM3	151-250	175	212
CFM4	251-500	350	424

CFM = Nominal Capacity of the exhaust fan. Savings calculatation use a common rating within the range, as shown in the "Assumed CFM" column

$Fan_{Efficiency, Baseline}$ = Efficacy for baseline fan[1]
1.7 CFM/Watt

$Fan_{Efficiency, Efficient}$ = Efficacy for efficient fan[2]
6.1 CFM/Watt

Hours = assumed annual run hours
2920[3]

Baseline Efficiencies

New standard efficiency exhaust-only ventilation fan operating in accordance with recommended ventilation rate indicated by ASHRAE 62.1 for commercial bathrooms during business hours.

High Efficiency

New efficient exhaust-only ventilation fan, operating in accordance with recommended ventilation rate indicated by ASHRAE 62.1 for commercial bathrooms during business hours.

Operating Hours

2870[3]

Load Shapes

113a Commercial Small Exhaust-only Vent Fan

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
113	Commercial Small Exhaust-only Vent Fan	Active	48.8%	19.5%	22.2%	9.5%	50.8%	72.4%

Net Savings Factors

Measures

VNTXCEIL	Exhaust fan, ceiling
VNTXVFAN	Exhaust fan, variable speed

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES
6014CUST [is base track]	6014CUST

Persistence
The persistence factor is assumed to be one.

Lifetimes
15 years[4]. Analysis period is the same as the lifetime.

Measure Cost
Incremental cost per installed fan is $110 for quiet, efficient fans[5].

O&M Cost Adjustments
There are no O&M Cost Adjustments for this measure.

Fossil Fuel Description
There are no fossil fuel savings for this measure.

Footnotes

[1] Weighted average of 20 best-selling ceiling exhaust fans at Grainger on 6/26/2017 using assumed sales distribution, 2017 Base-Efficacy sheet of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx

[2] Average of fans installed through EVT custom projects 2012-2016, 2017 EE-Efficacy sheet of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx

[3] Median of run hours of fans installed through EVT custom projects 2008-2011, Cell C67 on 2017 EE-Efficacy tab of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx.

[4] Estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for residential whole-house fans, 19 for residential thermostatically-controlled attic fans, and 15 years for several commercial measures.

[5] Based on historical incremental costs from EVT custom project data (2012-2016). Refer to Cell H59 on 2017 EE-Efficacy tab of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx.

Package Terminal Heat Pump (Hotel Room)

Measure Number: I-B-6 b
Portfolio: EVT TRM Portfolio 2019-08
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: HVAC

Update Summary

Updated the baseline and efficient metrics to meet federal efficiency standards. Interestingly enough, the code of federal regulations efficiency standards for PTAC and PTHP exceed those stipulated in VT 2015 CBES. Updated the baseline and efficient metrics to meet 10 CFR 431.97(c)). Baseline is defined as a code-compliant PTAC with electric resistance heating and the efficient scenario is a code-compliant PTHP. As both units have the same code standards for cooling EER (effective for PTACs in January 2017), there are no associated cooling savings for this measure.

Additionally, there were some revisions made to the 8760 analysis that calculates the deemed savings for this measure. In the analysis file, the following revisions were made:

- Updated the monthly hotel occupancy rates. The original rates were sourced from some VT benchmarking summary that I could no longer access. Overall, some of the rates looked small to borderline unreasonable. For instance, we were claiming hotel occupancy rates for rooms in May was 22.7%, 46.5% in the summer months, and the list goes on. Revised the monthly hotel occupancy rates to national averages, as sourced from Statista, that seem much more reasonable.
- Revised the cut-off temperature for the heat pump from 24ºF to 35ºF. This lower bound temperature was when the heat pump switched to electric resistance heating. Through research of available units it appeared the original 24ºF mark may have been too aggressive and unreasonable. Through research and communication with Charlie Carpenter, EVT, the 35ºF value was developed.
- As a result of these revisions, along with some errors corrected in how the loadshape was being calculated, a new loadshape for this measure was drafted.
- Revised the incremental cost.
- Additionally, made minor edits to the measure description and source notes to be more transparent and clear on the characterization assumptions.

Referenced Documents

- EERE-2012-BT-STD-0029-0044
- NYSERDA PTHP Market Development_Oct 2018
- PTHP Analysis_Revised_v3

Description

This measure characterizes the installation of a package terminal heat pump (PTHP) replacing a packge terminal air conditioner (PTAC) with electric resistance heat. PTHP's are predominantly used in hotel and motel accomodations, and are designed to supply each guest room with individual heating and air conditioning. However, the efficacy of PTHP's in cold-climates are diminished as they don't have a good means of dealing with frost build up on the coils. As a result, the heat pump compressor tends to shut off in colder temperatures[1] and the system reverts to electric resistance heating. An average system capacity of 9,000 Btu/h[2] was assumed.

This program will be targeted exclusively to hotels and motels likely to have existing PTAC units with electric resistance heat. While there may be applications for PTHP equipment in the context of new construction, the baseline is difficult to generalize. Therefore new construction applications will be handled through a custom process.

Program Type

Calculation Type: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Downstream

Program Delivery / Implementation Type

Baseline Efficiencies

The baseline reflects a code compliant PTAC with electric resistance heat.[3]

High Efficiency

The efficient equipment is a code compliant PTHP. [4]

Algorithms

Electric Demand Savings

Electric energy and demand savings are deemed and based on an hourly, 8760 analysis of TMY3 data, on an installed PTHP with a capacity of 9,000 Btu/h. The analysis revealed full load cooling hours of 814 and full load heating hours of 306 for the heat pump (with an additional 1,038 full load heating hours for the electric resistance backup, not included in the analysis).[5]

ΔkW	= 0.2585 kW

Symbol Table

Fossil Fuel Savings
N/A

Water Savings
N/A

Electric Energy Savings

ΔkWh	= 558 kWh

Where:

ΔkW	=	Gross customer connected load kW savings for the measure
ΔkWh	=	Gross customer average annual kWh savings for the measure

Mid-Life Savings Adjustment

N/A

Load Shapes

114b PTHP, Hotel

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
114	PTHP, Hotel	Active	41.1%	51.5%	1.0%	6.4%	3.2%	0.0%

Net Savings Factors

Measures

ACEHPPTL	Package terminal heat hump

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro

Lifetimes
15 years

Measure Cost
$100[6]

O&M Cost Adjustments
There are no standard operation and maintenance cost adjustments used for this measure.

Persistence
The persistence factor is assumed to be one.

Reference Tables
Item Code: BES-PTHP-H

Footnotes

[1] For the purposes of the analysis, the lower bound outdoor air temperature threshold at which heat pump feature operates was determined to be 35ºF. Below this temperature the unit shifts to resistance heat mode as per; "High Performance Packaged Terminal Heat Pump Market and Development Research Report", NYSERDA, October 2018. The 35ºF threshold was estimated from the page ES-2 in the report when it stated; "Most PTHPs operate as heat pumps only down to the 30s."

[2] The 9,000 Btu/h average capacity of a PTHP is sourced from the "High Performance Packaged Terminal Heat Pump Market and Development Research Report", NYSERDA, October 2018, page 4. The study indicates that 50% of the U.S. PTAC and PTHP market is comprised of 9,000 Btu/h units, with other common sizes being 7,000 Btu/h and 12,000 Btu/h.

[3] Federal efficiency standards exceed 2015 Vermont Commercial Building Energy Standards (Table C403.2.3(3)). As a result, baseline PTAC cooling efficiency is sourced from the Code of Federal Regulations (10 CFR 431.97(c)) for standard equipment size, with a capacity => 7,000 Btu/h and <= 15,000 Btu/h, and manufactured on or after January 1, 2017.

[4] Federal efficiency standards exceed 2015 Vermont Commercial Building Energy Standards (Table C403.2.3(3)). As a result, efficient PTHP heating and cooling efficiencies are sourced from the Code of Federal Regulations (10 CFR 431.97(c)) for standard equipment size, with a capacity => 7,000 Btu/h and <= 15,000 Btu/h, and manufactured on or after October 8, 2012.

[5] Full load heating and cooling hours are based on an hourly, 8760 analysis of TMY3 data, and assumes a balance point of 55ºF; an unoccupied setback of 5ºF; the heat pump providing heating down to 35ºF before switching to electric resistance; an estimate on sites employing setback controls (50%); monthly occupancy rates for accomodations; and an assumption that the equipment is oversized by 25% on average. For more detail on the analysis, please see "PTHP Analysis_Revised_v3.xlsx".

[6] "High Performance Packaged Terminal Heat Pump Market and Development Research Report", NYSERDA, October 2018, page ES-2

Advanced Thermostats

Measure Number: I-D-1 b
Portfolio: EVT TRM Portfolio 2019-01
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: HVAC

Update Summary

Updated to bring the Fe (auxiliary electric heat from fans/pumps) in line with the new assumption for Residential. Updating savings accordingly.

Referenced Documents

- VT CI Existing Buildings Market Assessment and Characterization_2012-10-6_FINAL
- VT CI New Construction Market Assessment and Characterization__FINAL_2012-12-21
- IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG
- Studies informing the TRM Savings Characterization for Advanced Thermostats
- VGS Usage Regression Work_04182017
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- Programmable Thermostats Furnace Fan Analysis
- SMB-Advanced Thermostat_01102019

Description

This measure characterizes the energy savings from the installation of a new thermostat(s) in a small to medium business location, to reduce heating and cooling consumption through a configurable schedule of temperature set-points (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[1] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations.

The measure assumes that the advanced thermostat is controlling a portion of the buildings heating/cooling load and, in the absence of small business specific assumptions, is assumed to control a similar load as Residential applications. This will be revised as data is collected on this small business application. Efficiency Vermont will track and provide incentives for up to six advanced thermostats per commercial building.

The thermostat must be installed and connected with the manufacturer in order to be eligible for a rebate.

Baseline Efficiencies

The baseline mix of programmable v manual thermostats for small to medium business customers is 89% manual and 11% programmable for existing buildings[2].

For New Construction, the baseline is a programmable thermostat due to code requirements.

Efficient Equipment

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[3] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

Algorithms

Electric Demand Savings

$\Delta kW = Max(\Delta kWh_{heating} / EFLH_{heat}, \Delta kWh_{cooling} / EFLH_{cool})$

Symbol Table

Electric Energy Savings

$\Delta kWh = \Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating}$ = %ElectricHeat × Elec_Heating_Consumption × %Controlled × Heating_Reduction + (ΔMMBtu × F_e × 293)

$\Delta kWh_{cooling}$ = %AC × (($EFLH_{cool}$ × Capacity × 1/SEER)/1000) × Cooling_Reduction

Symbol Table

Fossil Fuel Savings

ΔMMBtu = Σ (%FossilHeat × Heating_Consumption × %Controlled) × Heating_Reduction

Where:

%AC = Fraction of customers with central air-conditioning

Central air conditioning?	%AC
Yes	100%
No	0%
Unknown	56%[6]

%Controlled = Assumed percentage of total heating load being controlled by thermostat.

= 69% for Existing Buildings and 53% for NC[7]

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat	
	Existing Buildings[8]	New Construction[9]
Electric	100%	
Fossil Fuel	0%	
Unknown	25%	61%

%FossilHeat = Percentage of heating savings assumed to be fossil fuel (note for the 'unknown' category natural gas is not included as it will be known that it is not natural gas)

Heating fuel	%FossilHeat	
	Existing Buildings[8]	New Construction[9]

Electric		0%	
Fossil Fuel		100%	
Unknown	Oil	27%	0%
	Propane	48%	39%

ΔkW	=	Annual demand reduction.
$\Delta kWh_{cooling}$	=	Electric savings from cooling energy usage reductions
$\Delta kWh_{heating}$	=	Electric savings from heating energy usage reductions. This accounts for both electric heat (heat pumps) and fan/pump savings in the case of a fossil heating system.
ΔkWh	=	Electrical savings are a function of both heating and cooling energy usage reductions.
ΔMMBtu	=	Fuel savings if fossil fuel heating system
293	=	kWh per MMBtu
Capacity	=	Capacity of AC unit. (Note: One refrigeration ton is equal to 12,000 Btu/hr.) = 41,400 Btuh/hr[10]
Cooling_Reduction	=	Assumed percentage reduction in total cooling energy consumption due to installation of advanced thermostat = 8.0%[11]
$EFLH_{cool}$	=	Estimate of annual full load cooling hours for air conditioning equipment. = 755[4]
$EFLH_{heat}$	=	Assumed Equivalent Full Load Hours for heating = 1062[5]
Elec_Heating_Consumption	=	Estimate of annual heating consumption for heat pump heated buildings:

Elec_Heating_Consumption (kWh)	
Existing Buildings	New Construction
8,273[12]	6,416[13]

F_e	=	Furnace fan / boiler pump energy consumption as a percentage of annual fuel consumption = 1.91%[14]
Heating_Consumption	=	Estimate of annual heating consumption

	Gas_Heating_Consumption (MMBtu)	
	Existing Buildings[17]	New Construction[18]
Gas	81	67
Oil	84	70
Unknown	82	67

Heating_Reduction	=	Assumed percentage reduction in total heating energy consumption due to advanced thermostat

Program	Existing Thermostat Type	Heating_Reduction[15]
Existing Buildings	Unknown (Blended)	8.0%
New Construction	Programmable	5.6%

SEER	=	The cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

SEER	
Existing Buildings	New Construction
11.7[16]	20.2[16]

Load Shapes

124c SMB Advanced Thermostat - Fossil Heat & Cooling
125b SMB Advanced Thermostat - Electric Heat & Cooling
126c SMB Advanced Thermostat - Unknown Heat & Cooling
17b Commercial Space Heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
124	SMB Advanced Thermostat - Fossil Heat & Cooling	Active	20.7%	14.5%	41.3%	23.5%	1.5%	34.3%
125	SMB Advanced Thermostat - Electric Heat & Cooling	Active	35.2%	38.8%	15.7%	10.3%	17.9%	23.2%
126	SMB Advanced Thermostat - Unknown Heat & Cooling	Active	31.2%	32.2%	22.6%	13.9%	14.2%	34.7%
17	Commercial Space Heat	Active	43.2%	52.3%	1.6%	3.0%	17.9%	0.6%

Net Savings Factors

Measures

SHESMART	Advanced Thermostat

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Lifetimes

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[19] based upon equipment life only.

Measure Cost

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used, with a default of $265 ($225 for the thermostat and $40 for labor). For other program types the average incremental cost for the new installation measure is assumed to be $175[20].

For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150[21].

Prescriptive Savings Tables

Deemed savings are provided below[22].

Savings Type	Fuel	Existing Buildings							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Code		ADVSTATSMBE1	ADVSTATSMBE2	ADVSTATSMBE3	ADVSTATSMBE4	ADVSTATSMBE5	ADVSTATSMBE6	ADVSTATSMBE7	ADVSTATSMBE8
Heating	Natural Gas (MMBTU)	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	4.6	4.6	0.0	0.0	0.0	1.3
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	4.5	4.5	0.0	2.1
Heating	Electric (kWh)	25	25	26	26	25	25	457	133
Cooling	Electric (kWh)	214	0.0	214	0.0	214	0.0	214	120
	Total MMBTU	4.5	4.5	4.6	4.6	4.5	4.5	0.0	3.4
	Total kWh	239	25	240	26	239	25	670	253
	kW	0.2831	0.0238	0.2831	0.0247	0.2831	0.0238	0.4300	0.1585
	Loadshape Used	124 - SMB Advanced Thermostat - Fossil Heat & Cooling	17 - Commercial Space heat	124 - SMB Advanced Thermostat - Fossil Heat & Cooling	17 - Commercial Space heat	124 - SMB Advanced Thermostat - Fossil Heat & Cooling	17 - Commercial Space heat	125 - SMB Advanced Thermostat - Electric Heat & Cooling	126 - SMBAdvanced Thermostat - Unknown Heat & Cooling

Savings Type	Fuel	New Buildings							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Code		ADVSTATSMBN1	ADVSTATSMBN2	ADVSTATSMBN3	ADVSTATSMBN4	ADVSTATSMBN5	ADVSTATSMBN6	ADVSTATSMBN7	ADVSTATSMBN8
Heating	Natural Gas (MMBTU)	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	2.1	2.1	0.0	0.0	0.0	0.0
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	2.0	2.0	0.0	0.8
Heating	Electric (kWh)	12	12	12	12	12	12	190	121
Cooling	Electric (kWh)	124	0.0	124	0.0	124	0.0	124	69
	Total MMBTU	2.0	2.0	2.1	2.1	2.0	2.0	0.0	0.8
	Total kWh	136	12	136	12	136	12	314	190
	kW	0.1640	0.0111	0.1640	0.0115	0.1640	0.0111	0.1793	0.1135
	Loadshape Used	124 - SMB Advanced Thermostat - Fossil Heat & Cooling	17 - Commercial Space heat	124 - SMB Advanced Thermostat - Fossil Heat & Cooling	17 - Commercial Space heat	124 - SMB Advanced Thermostat - Fossil Heat & Cooling	17 - Commercial Space heat	125 - SMB Advanced Thermostat - Electric Heat & Cooling	126 - SMB Advanced Thermostat - Unknown Heat & Cooling

Footnotes

[1] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home’s thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[2] Based on findings for Office building type from 'Figure 63: Saturation of HVAC System Control Types by Facility Type' from the 2016 VT Business Sector Market Characterization and Assessment Study, April 30 201. Note EMS (Energy Management Systems) were found in 25% of the Offices. It is assumed that these would not be installing Advanced Thermostats and so are not included in the baseline mix.

[3] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. Efficiency Vermont will be exploring ways to better utilize this data once the program is underway and once the ENERGY STAR specification and program process is finalized.

[4] EFLH for commercial air conditioning are derived directly from the following KEMA report. KEMA, "C&I Unitary HVAC Load Shape Project Final Report", Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, August 2, 2011. Pg. 57, Table 3-1.

[5] Commercial FLH is a weighted average of commercial FLH values from New York Joint Utiliites,"New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (Version 4)," April 29, 2016 and Vermont building data provided by Cadmus. See file EVT_Commercial EFLH_Analysis_July 2017 for calculation details.

[6] Value is for Office Building Type as representative of small and medium business customer likely to participate, from Business Sector Market Assessment and Baseline Study: Existing Commercial Buildings, Vol. 1, Final Report, prepared by KEMA for the Department of Public Service, July 10, 2009, Table 5-9

[7] Consistent with Residential assumptions; Based on review of # of thermostats per home data from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013 and Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. See 'Advanced Thermostat Analysis_04182017_FINAL.xls'

[8] Unknown values are based upon data for Efficiency Vermont from 'Figure 46 Heating System Fuel Type by EEU' from 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017. Percentage for electricity is reduced to only include heat pump systems as resistance heat will not be controlled by an Advanced Thermostat (heat pump percentage is based on values for non-VT gas from 'Figure 47 Distribution of Heating System Types by Facility Size and VT Gas Territory' from the same study). Note that the unknown values do not include natural gas as this will be known.

[9] Unknown values are based upon data for Efficiency Vermont from 'Figure 128 Heating System Fuel Type by EEU' from 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017. Percentage for electricity is reduced to only include heat pump systems as resistance heat will not be controlled by an Advanced Thermostat (heat pump percentage is based on values for non-VT gas from 'Figure 129 Distribution of Heating System Types by Facility Size and VT Gas Territory' from the same study). Note that the unknown values do not include natural gas as this will be known.

[10] Consistent with Residential assumptions: TAG Agreement 2017.

[11] Consistent with Residential assumptions; This assumption is based upon the review of many evaluations from other regions in the US (see “Studies informing the TRM Savings Characterization for Advanced Thermostats.docx”). These sources, are from different regions, products, and program delivery designs, but collectively form a sound basis, and directional guidance for the existence and magnitude of cooling savings. Because cooling savings are more volatile than those for heating due to variables in control behaviors, population, and product factors, conservatism is warranted and 8% is considered a conservative estimate based upon the array of results from these studies. Further evaluation and regular review of this key assumption is encouraged.

[12] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See “Advanced Thermostat Analysis_04182017_FINAL.xlsx”, for details.

[13] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump

load is delivered in heat pump mode v resistance. See "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[14] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For boilers, fuel and electric use values were taken from Table 10.1, page 30 of James Lutz et al., Lawrence Berkeley Laboratory "Modeling energy consumption of residential furnaces and boilers in US homes". This was then weighted by furnace v boiler distribution to estimate an average value of 1.91%.

For Small Business this is assumed to be consistent with Residential.

[15] Savings of 8.8% for manual, and 5.6% for programmable thermostats are taken from Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value for existing buildings. The weighting of manual to programmable thermostats for when unknown is based upon Office building type from 'Figure 63 Saturation of HVAC System Control Types by Facility Type' of 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017. Note EMS (Energy Management Systems) were found in 25% of the Offices. It is assumed that these would not be installing Advanced Thermostats and so are not included in the baseline mix.

[16] SEER assumption for existing buildings is based on 'Table 16 Cooling Efficiency of Single-Zone Unitary HVAC Systems <5.5 tons' and for new construction 'Table 56 Cooling Efficiency of Single-Zone Unitary HVAC systems' from 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017.

[17] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[18] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[19] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[20] Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

[21] Assumed to be $225 minus $75 for programmable thermostat.

[22] See 'SMB Advanced Thermostat.xls' for calculations.

Residential Fan—Quiet, Exhaust-Only Continuous Ventilation

Measure Number:	III-E-1 d
Portfolio:	EVT TRM Portfolio 2017-06
Status:	Active
Effective Date:	2017/1/1
End Date:	[None]
Program:	Existing Homes
End Use:	HVAC

Update Summary

This is part of EVT TRM reliability, as well as adding a two tier set up to account for efficiency differences between ENERGY STAR and ENERGY STAR Most Efficient residential ventilation bath fans.

Referenced Documents

- ASHRAE 62.2 Section 4.1 Whole House Ventilation
- measure_life_GDS[1]
- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- EVT_ENERGY STAR Ventiltion Fan_Analysis_May 2017

Description

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2. This measure applies to the Low Income Single Family, Multifamily, Residential New Construction, and Existing Homes programs.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

$\Delta kW = CFM \times (1/Fan_{Efficiency, Baseline} - 1/Fan_{Efficiency, Efficient})/1000$

$\Delta kW = CFM \times (1/Fan_{Efficiency, Baseline} - 1/Fan_{Efficiency, Most Efficient})/1000$

Symbol Table

Electric Energy Savings

$\Delta kWh = Hours \times \Delta kW$

Where:

ΔkW	=	Gross customer connected load kW savings per qualified ventilation fan and controls.
ΔkWh	=	Gross customer annual kWh savings per qualified ventilation fan and controls.
CFM	=	Nominal Capacity of the exhaust fan, 50 CFM[1]
$Fan_{Efficiency, Effcient}$	=	Average efficacy for ENERGY STAR fan, 4.84 CFM/Watt[5884]
$Fan_{Efficiency, Most Efficient}$	=	Average efficacy for ENERGY STAR fan, 12.48 CFM/Watt[2]
$Fan_{Efficiency, Baseline}$	=	Average efficacy for baseline fan, 2.8 CFM/Watt[3]
Hours	=	assumed annual run hours, 8760 for continuous ventilation

Baseline Efficiencies

Baseline efficiency is assumed to be Vermont Residential Building Energy Code, which is 2.8 CFM/Watt.

High Efficiency

New efficient criteria is assumed to be 4.84 CFM/Watt for ENERGY STAR Vent Fans, and 12.48 CFM/Watt for ENERGY STAR Most Efficient Vent Fans.

Operating Hours

Continuous, 8760.

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%

Net Savings Factors

Measures

VNTXCEIL	Exhaust fan, ceiling

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
5102OLS [5100EPEP]	Retail Efficient Products On-line Store

Persistence

The persistence factor is assumed to be one.

Lifetimes

19 years[4]

Analysis period is the same as the lifetime.

Measure Cost

Incremental cost per installed fan is $69.65 for quiet, efficient fans.[5]

O&M Cost Adjustments

Savings Summary

	ΔkW	ΔkWh
ENERGY STAR Vent Fan	0.008	66.0
ENERGY STAR Most Efficient Vent Fan	0.014	121.3

[6]

Fossil Fuel Description

Footnotes

[1] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

[2] Average CFM/watt for ENERGY STAR certified fans from current Qualified Products List

[3] 2015 Vermont Resiential Business Energy Standard, Table R403.6.1 Mechanical Ventilation System Fan Efficacy

[4] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.

[5] NEEP Incremental Cost Study Phase Two, Page 34, Table 55. Costs are weighted averages based on ENERGY STAR QPL CFM model counts.

[6] Refer to analyis document: EVT_ENERGY STAR Ventilation Fan_Analysis_May 2017.xlsx.

Outdoor Reset Control

Measure Number: III-F-4 a
Portfolio: 74
Status: Active
Effective Date: 2012/1/1
End Date: [None]
Program: Multifamily
End Use: HVAC

Referenced Documents

- http://www.heat-timer.com/en/EducationDetail.aspx?Id=3
- DTE Energy Boiler Reset Factsheet
- OutdoorResetARCreduced

Description

A boiler outdoor reset control regulates the boiler water temperature used for space heating, reducing the temperature when the outside temperature is higher, during fall and spring, improving boiler efficiency and reducing heat loss off the circulating loop. Outdoor reset controls are typically standard on high efficiency gas boiler models, but are an add on for oil boiler units. This measure characterization documents additional savings that will be claimed when an efficient boiler is installed in place of a baseline model without the controls. The AFUE rating used to claim savings for this upgrade (in the Comprehensive Thermal Measure) does not capture savings associated with the Outdoor Reset Control. Note that if specifics from the installation are available (i.e. the length and insulation level of the circulating loop, the boiler size and run time), then a custom tool will be used to capture site specific savings.

Estimated Measure Impacts

Algorithms

Fossil Fuel Savings

If specifics from the installation are available (i.e. the length and insulation level of the circulating loop, the boiler size and run time), then a custom tool will be used to capture site specific savings.

ΔMMBtu	= SF × Annual Heat Load

Where:

ΔMMBtu	=	
Annual Heat Load	=	Annual Heating Load of building served by boilers (MMBtu/year)
		= Custom (based on heating load result from modeling)
SF	=	Savings Factor for Boilers with Outdoor Reset control
		= 5%[1]

Baseline Efficiencies

Standard boiler without outdoor reset control.

High Efficiency

Boiler with outdoor reset control.

Operating Hours

Load Shapes

n/a. No electric savings.

Net Savings Factors

Measures

SHECONTR	Improved space heating controls

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	SHECONTR	1.00	1.00
MF Mkt NC	6019MFNC	SHECONTR	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years

Analysis period is the same as the lifetime.

Measure Cost

Outdoor reset control is standard on high efficiency gas boiler models. The incremental cost of this measure is therefore assumed to be $0, since the incremental cost of the boiler is captured in the Comprehensive Thermal measure.

For high efficiency oil boiler models, outdoor reset controls are not standard but an optional add on. For oil boilers therefore the incremental cost is assumed to be $1000[2].

O&M Cost Adjustments

Fossil Fuel Description

Footnotes

[1] Conservative estimate based on a number of sources:

1. "5%"; http://www.dteenergy.com/pdfs/boilerResetFactSheet.pdf
2. "15% or more"; http://www.heat-timer.com/en/EducationDetail.aspx?Id=3
3. "5 to 30%"; http://www.arcmech.com/images/fm/pdir17/OutdoorResetARCreduced.pdf

[2] Based on EVT conversations with local HVAC contractors.

Advanced Thermostat Optimization Services

Measure Number: IV-J-3 c
Portfolio: EVT TRM Portfolio 2019-02
Status: Active
Effective Date: 2019/1/1
End Date: 2021/12/31
Program: Efficient Products Program
End Use: HVAC

Update Summary

Updated values to make consistent with recent Advanced Thermostat update (PF 2018-11) and to include MF assumptions.

Referenced Documents

- VGS Usage Regression Work_04182017
- Nest_seasonal_savings_white_paper
- Nest_SeasonalSavings_Impacts_Winter1617_VEIC
- dcseu-seasonal-savings-proposal-updated-pdf
- EVT_AdvThermostatOptimized v4

Description

This measure provides the characterization of *additional* savings to the Advanced Thermostat measure which are achieved for participants enrolling in add-on optimization services which are designed to enhance the savings from their existing advanced thermostat. Software add ons deploy set point altering algorithms to generate additional heating and cooling savings than would be realized from just the advanced thermostat alone. Details of the participants enrolling together with an end of year report detailing those participants and the impacts on setback resulting from the software will be provided to Efficiency Vermont for future measure refinement.

Baseline Efficiencies

The baseline is a customer with an advanced thermostat that has not enrolled on an additional optimization program.

Efficient Equipment

The efficient case is a participant that has enrolled on an optimization program.

Algorithms

Electric Demand Savings

$$\Delta kW = Max(\Delta kWh_{CoolingOptimized} / EFLH_{Cool}, \Delta kWh_{HeatingOptimized} / EFLH_{Heat})$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = \Delta kWh_{CoolingOptimized} + \Delta kWh_{HeatingOptimized}$$

$$\Delta kWh_{CoolingOptimized} = NewCoolingConsumption \times Cooling_{OptimizedlReduction}$$

$$\Delta kWh_{HeatingOptimized} = NewElecHeatingConsumption \times Heating_{OptimizedReduction}$$

Symbol Table

Fossil Fuel Savings

$$\Delta MMBtu = NewFuelHeatingConsumption \times Heating_{OptimizedReduction}$$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure.
$\Delta kWh_{CoolingOptimized}$	=	Additional cooling savings from participants enrolled in Optimization program.
$\Delta kWh_{HeatingOptimized}$	=	Additional heating savings from participants enrolled in Optimization program.
ΔkWh	=	Gross customer annual kWh savings for the measure
$\Delta MMBtu$	=	Gross customer annual MMBtu fuel savings for the measure
$Cooling_{OptimizedlReduction}$	=	Assumed percentage reduction in household cooling energy consumption due to Nest Seasonal Savings. = 3.5%[3]
$EFLH_{Cool}$	=	Estimate of annual household full load cooling hours for air conditioning equipment. = 375[1]
$EFLH_{Heat}$	=	Assumed Equivalent Full Load Hours for heating (see table below)
$Heating_{OptimizedReduction}$	=	Assumed percentage reduction in household heating energy consumption due to Optimized add on. = 3.5%
NewCoolingConsumption	=	New cooling consumption - i.e. calculation of consumption after subtracting the base level savings from the Advanced Thermostat measure. See 'EVTOptimizedSavings.xls' for more information.
NewElecHeatingConsumption	=	New heating consumption - i.e. calculation of consumption after subtracting the base level savings from the Advanecd Thermostat measure. See 'EVT_AdvThermostatOptimized.xls' for more information.
NewFuelHeatingConsumption	=	New heating consumption - i.e. calculation of consumption after subtracting the base level savings from the Advanced Thermostat measure. See 'EVT_AdvThermostatOptimized.xls' for more information.

EFLH[2]	
Existing Homes	New Construction
878	855

Load Shapes

5b Residential Space heat
120d Advanced Thermostat - Fossil Heat & Cooling
122d Advanced Thermostat - Unknown Heat & Cooling
121d Advanced Thermostat - Electric Heat & Cooling
11b Residential A/C

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%
120	Advanced Thermostat - Fossil Heat & Cooling	Active	14.1%	14.9%	40.5%	30.5%	2.8%	16.0%

122	Advanced Thermostat - Unknown Heat & Cooling	Active	35.6%	46.5%	10.2%	7.7%	25.0%	9.3%
121	Advanced Thermostat - Electric Heat & Cooling	Active	36.5%	47.8%	9.0%	6.7%	25.0%	8.0%
11	Residential A/C	Active	6.6%	3.8%	51.1%	38.6%	0.0%	16.0%

Net Savings Factors

Measures

SHESMART	Advanced Thermostat

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Lifetimes

The expected measure life for savings associated with the Nest Seasonal Savings program is 1 year.

Measure Cost

The cost to enroll is $6.00 per participant for a single year[4]

Prescriptive Savings Tables

Deemed savings are provided below. The first two tables provide default savings for when implementation does not allow the building or heating type to be known.[5]

Summer Seasonal Program:

Savings Type	Fuel	Weighted Average
Cooling	Electric (kWh)	24.9
Loadshape	kW	0.0664
	11a Residential AC	

Winter Seasonal Program:

Savings Type	Fuel	Weighted Average		
		Natural Gas	Non Natural Gas	HP Electric Heat
Heating	Natural Gas (MMBTU)	1.8	0.0	0.0
Heating	Oil (MMBTU)	0.0	1.0	0.0
Heating	LP (MMBTU)	0.0	0.7	0.0
Heating	Electric (kWh)	10.0	17.9	181.9
	Total MMBTU	1.8	1.7	0.0
	Total kWh	10.0	17.9	181.9
	kW	0.0114	0.0204	0.2071
	Loadshape	5a Residential Space heat		

Savings Type	Fuel	Single Family Existing Homes							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	1.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	1.9	1.9	0.0	0.0	0.0	1.1
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	1.8	1.8	0.0	0.3
Heating	Electric (kWh)	10.1	10.1	10.4	10.4	10.1	10.1	184.0	7.7
Cooling	Electric (kWh)	25.0	0.0	25.0	0.0	25.0	0.0	25.0	1.6
	Total MMBTU	1.8	1.8	1.9	1.9	1.8	1.8	0.0	1.4
	Total kWh	35.1	10.1	35.4	10.4	35.1	10.1	209.0	9.3
	kW	0.0667	0.0115	0.0667	0.0119	0.0667	0.0115	0.2096	0.0087
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Savings Type	Fuel	Residential New Construction							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	1.2	1.2	0.0	0.0	0.0	0.2
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	1.2	1.2	0.0	1.0
Heating	Electric (kWh)	6.5	6.5	6.8	6.8	6.5	6.5	112.4	6.6
Cooling	Electric (kWh)	16.3	0.0	16.3	0.0	16.3	0.0	16.3	0.6
	Total MMBTU	1.2	1.2	1.2	1.2	1.2	1.2	0.0	1.2
	Total kWh	22.8	6.5	23.1	6.8	22.8	6.5	128.7	7.2
	kW	0.0434	0.0076	0.0434	0.0080	0.0434	0.0076	0.1315	0.0077
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Savings Type	Fuel	Multi Family Existing Homes							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling

Heating	Natural Gas (MMBTU)	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.7
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.2
Heating	Electric (kWh)	5.3	5.3	5.5	5.5	5.3	5.3	96.5	5.3
Cooling	Electric (kWh)	17.7	0.0	17.7	0.0	17.7	0.0	17.7	0.7
	Total MMBTU	0.9	0.9	1.0	1.0	0.9	0.9	0.0	1.0
	Total kWh	23.0	5.3	23.2	5.5	23.0	5.3	114.2	6.0
	kW	0.0472	0.0060	0.0472	0.0062	0.0472	0.0060	0.1099	0.0061
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Savings Type	Fuel	Multi Family New Construction							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	0.8	0.8	0.0	0.0	0.0	0.1
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	0.9	0.9	0.0	0.7
Heating	Electric (kWh)	4.5	4.5	4.7	4.7	4.5	4.5	76.9	4.5
Cooling	Electric (kWh)	15.6	0.0	15.6	0.0	15.6	0.0	15.6	0.3
	Total MMBTU	0.8	0.8	0.8	0.8	0.8	0.8	0.0	0.8
	Total kWh	20.0	4.5	20.2	4.7	20.0	4.5	92.5	4.8
	kW	0.0415	0.0052	0.0415	0.0055	0.0415	0.0052	0.0899	0.0053
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Footnotes

[1] EVT applied 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours for 375 hours.

[2] Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis.

[3] Based on findings from Nest "Seasonal Savings Impacts in Vermont", December 2016 through April 2017 (464 participating thermostats) and a deployment with over 20,000 units in Massachusetts (see attachment 1, page 12 of 'DCSEU Seasonal Savings Proposal_Updated'). The savings determined through these evaluations represent the average savings from all participants, including those that pull out or override the program.

These studies only looked at the impact on heating loads though significant cooling impacts have also been found (see 'Nest_seasonal_savings_white_paper.pdf). This measure assumes the same impact on cooling loads.

Note that through participation Efficiency Vermont will be gathering evaluation data to allow calculation of a EVT specific assumptions in the future.

[4] See attachment 1 of 'DCSEU Seasonal Savings Proposal_Updated'.

[5] See with 'EVT_AdvThermostatOptimized V3.xls' for the calculation. Note weighted average assumptions (for gas heated homes and non-gas heated homes) based on fuel mix from programmable thermostat sales October 2017 through March 2018.

Advanced Thermostats

Measure Number: RS-HVC-ADVT a
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: HVAC

Update Summary

Update to include additional savings from Thermostat Optimization (e.g. Nest Seasonal Savings and ecobee+) for a percentage of customers purchasing a new Advanced Thermostat measure. Seasonal savings is now available to all and will not be a separate utility sponsored program, so this will be the only Seasonal Savings that is claimed.

Update to assumptions based on Vermont Single-Family Existing Homes Onsite Report, 7/2018 and Vermont Residential New Construction Homeowner Survey Report, 5/2018.

Referenced Documents

- VT-RES-New-Construction-On-Site-Final-Report-2-13-13
- Studies informing the TRM Savings Characterization for Advanced Thermostats
- VT SF Existing Homes Onsite Report_final 021513
- VGS Usage Regression Work_04182017
- Programmable Thermostats Furnace Fan Analysis
- IL SAG Smart Thermostat Preliminary Gas Impact Findings2015-12-08 to IL SAG
- Efficiency Vermont Summer 2018 Seasonal Savings
- Seasonal Savings Impacts Winter 2019_20_ Efficiency Vermont
- EVT Advanced Thermostat and Optimization_2020

Description

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature set-points (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[1] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations.

Savings estimates are provided for Existing Homes, Residential New Construction and Multifamily Existing and New. Note all savings will be claimed through Efficient Products, however the baseline for New Construction is a programmable thermostat (due to code requirements) while the baseline for Existing Homes and Multifamily Existing is assumed to be a mix of manual and programmable thermostats.

The measure assumes that the advanced thermostat is controlling a portion of the whole home's heating/cooling load. Efficiency Vermont will track and provide incentives for up to two advanced thermostats per residence.

The thermostat must be installed and connected with the manufacturer in order to be eligible for a rebate.

Baseline Efficiencies

For existing buildings the baseline is assumed to be a mix of programmable and manual thermostats. For New Construction, the baseline is a programmable thermostat.

Efficient Equipment

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[2] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

Algorithms

Electric Demand Savings

ΔkW = Max($\Delta kWh_{heating}$ / $EFLH_{heat}$, $\Delta kWh_{cooling}$/ $EFLH_{cool}$)

Symbol Table

Electric Energy Savings

ΔkWh = $\Delta kWh_{heating}$ + $\Delta kWh_{cooling}$

= (%ElectricHeat × (ThersmotatSavings + OptimizationSavings)) + FanSavings

$\Delta kWh_{heating}$ = (%ElectricHeat × ((Elec_Heating_Consumption × %Controlled × AdvThermostat_HeatReduction) + (Elec_Heating_Consumption × %Controlled × (1 - AdvThermostat_HeatReduction) × %OptSavingsHeat))) + (ΔMMBtu × F_e× 293)

$\Delta kWh_{cooling}$ = %AC × (ThermostatSavings + OptimizationSavings)

$\Delta kWh_{cooling}$ = %AC × ((($EFLH_{cool}$ × Capacity × 1/SEER)/1000) × AdvThermostat_CoolReduction) + ($EFLH_{cool}$ × Capacity × 1/SEER)/1000) × (1 - AdvThermostat_CoolReduction) × %OptSavingsCool))

Symbol Table

Fossil Fuel Savings

ΔMMBtu = Σ (%FossilHeat × (ThermostatSavings + OptimizationSavings))

ΔMMBtu = Σ (%FossilHeat × ((Heating_Consumption × %Controlled) × AdvThermostat_HeatReduction) + (Heating_Consumption × %Controlled) × (1 - AdvThermostat_HeatReduction) × %OptSavingsHeat)))

Where:

%AC = Fraction of customers with central air-conditioning

Central air conditioning?	%AC			
	Existing Homes	Residential New Construction	Multifamily Existing	Multifamily New Construction
Yes	100%			
No	0%			
Unknown	6.9%[5]	10.0%[5]	4.1%[6]	6.0%[7]

%Controlled = Assumed percentage of total heating load being controlled by thermostat.

= 76% for EH, 53% for RNC[8] and 94% for Multifamily[9].

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat
Electric	100%
Fossil Fuel	0%
Unknown	0%[10]

%FossilHeat = Percentage of heating savings assumed to be fossil fuel (note for the 'unknown' category natural gas is not included as it will be known that it is not natural gas). Multifamily is assumed to be the same as the equivalent single family values below.

Heating fuel		%FossilHeat	
		Existing Buildings[22]	New Construction[23]
Electric		0%	
Fossil Fuel		100%	
Unknown	Oil	78%	18%
	Propane	22%	82%

%OptSavingsCool = Estimated additional cooling savings from users with Thermostat Optimization services.

= 0.65% [11]

%OptSavingsHeat = Estimated additional heat savings from users with Thermostat Optimization services.

= 0.79%[11]

ΔkW = Annual demand reduction.

$\Delta kWh_{cooling}$ = Electric savings from cooling energy usage reductions

$\Delta kWh_{heating}$ = Electric savings from heating energy usage reductions. This accounts for both electric heat (heat pumps) and fan/pump savings in the case of a fossil heating system.

ΔkWh = Electrical savings are a function of both heating and cooling energy usage reductions.

ΔMMBtu = Fuel savings if fossil fuel heating system

293 = kWh per MMBtu

AdvThermostat_CoolReduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat

=8.0%[12]

AdvThermostat_HeatReduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

Program	Existing Thermostat Type	Heating_Reduction[13]
Existing Homes	Unknown (Blended)	7.5%
Multifamily Existing	Unknown (Blended)	8.1%
New Construction	Programmable	5.6%

Capacity = Capacity of AC unit. (Note: One refrigeration ton is equal to 12,000 Btu/hr.)

= 37,200 Btuh[14] for single family homes and 18,542 Btuh[15] for multifamily units

$EFLH_{cool}$ = Estimate of annual household full load cooling hours for air conditioning equipment.

= 375[3]

$EFLH_{heat}$ = Assumed Equivalent Full Load Hours for heating. Multifamily is assumed to be the same as the equivalent single family values below.

EFLH[4]	
Existing Homes	New Construction
878	855

Elec_Heating_Consumption = Estimate of annual household heating consumption for heat pump heated homes:

Elec_Heating_Consumption (kWh)			
Existing Homes	Residential New Construction	MultiFamily Existing	Multifamily New Construction
8,271[16]	6,416[17]	3,180[18]	2,467[18]

F_e = Furnace fan / boiler pump energy consumption as a percentage of annual fuel consumption

= 1.91%[19]

FanSavings = Electric savings from reduced furnace fan usage with fuel heat.

Heating_Consumption = Estimate of annual household heating consumption

	Gas_Heating_Consumption (MMBtu)			
	Existing Homes[24]	Residential New Construction[25]	Multifamily Existing[18]	Multifamily New Construction[18]
Gas	80	67	31	26
Oil	85	70	33	27
Unknown	82	67	32	26

OptimizationSavings = Additional savings for Thermostat Optimization deployment

SEER = The cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh). Multifamily is assumed to be the same as the equivalent single family values below.

SEER

Existing Homes	New Construction
11.4[20]	15.0[21]

ThermostatSavings = Standard savings from Advanced Thermostat

Load Shapes

5b Residential Space heat
120d Advanced Thermostat - Fossil Heat & Cooling
122d Advanced Thermostat - Unknown Heat & Cooling
121d Advanced Thermostat - Electric Heat & Cooling

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%
120	Advanced Thermostat - Fossil Heat & Cooling	Active	14.1%	14.9%	40.5%	30.5%	2.8%	16.0%
122	Advanced Thermostat - Unknown Heat & Cooling	Active	35.6%	46.5%	10.2%	7.7%	25.0%	9.3%
121	Advanced Thermostat - Electric Heat & Cooling	Active	36.5%	47.8%	9.0%	6.7%	25.0%	8.0%

Net Savings Factors

Measures

SHESMART	Advanced Thermostat

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Lifetimes

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[26] based upon equipment life only.

Measure Cost

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used, with a default of $265 ($225 for the thermostat and $40 for labor). For retail, Bring Your Own Thermostat (BYOT) programs[27], or other program types the average incremental cost for the new installation measure is assumed to be $175[28].

For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150[29].

Prescriptive Savings Tables

Deemed savings are provided below. See "EVT Advanced Thermostat and Optimization 2020.xls" for more details of the calculations.

Savings Type	Fuel	Existing Homes							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Codes:		ADV1THERMOEH1	ADV1THERMOEH2	ADV1THERMOEH3	ADV1THERMOEH4	ADV1THERMOEH5	ADV1THERMOEH6	ADV1THERMOEH7	ADV1THERMOEH8
Heating	Natural Gas (MMBTU)	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	5.0	5.0	0.0	0.0	0.0	4.2
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	5.0	5.0	0.0	1.1
Heating	Electric (kWh)	27.8	27.8	29.4	29.4	27.8	27.8	515.5	29.1
Cooling	Electric (kWh)	105.2	0.0	105.2	0.0	105.2	0.0	105.2	7.3
	Total MMBtu	5.0	5.0	5.3	5.3	5.0	5.0	0.0	5.2
	Total kWh	133.0	27.8	134.6	29.4	133.0	27.8	620.7	36.3
	kW	0.2805	0.0317	0.2805	0.0335	0.2805	0.0317	0.5871	0.0331

Savings Type	Fuel	Residential New Construction							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Codes:		ADV1THERMONC1	ADV1THERMONC2	ADV1THERMONC3	ADV1THERMONC4	ADV1THERMONC5	ADV1THERMONC6	ADV1THERMONC7	ADV1THERMONC8
Heating	Natural Gas (MMBTU)	2.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	2.3	2.3	0.0	0.0	0.0	0.4
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	2.2	2.2	0.0	1.9
Heating	Electric (kWh)	12.4	12.4	13.0	13.0	12.4	12.4	216.0	12.9
Cooling	Electric (kWh)	88.7	0.0	88.7	0.0	88.7	0.0	88.7	8.9
	Total MMBtu	2.2	2.2	2.3	2.3	2.2	2.2	0.0	2.3
	Total kWh	101.2	12.4	101.7	13.0	101.2	12.4	304.7	21.8
	kW	0.2367	0.0146	0.2367	0.0152	0.2367	0.0146	0.2526	0.0237

Savings Type	Fuel	Multifamily Existing							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Codes:		ADV1THERMOMF1	ADV1THERMOMF2	ADV1THERMOMF3	ADV1THERMOMF4	ADV1THERMOMF5	ADV1THERMOMF6	ADV1THERMOMF7	ADV1THERMOMF8
Heating	Natural Gas (MMBTU)	2.6	2.6	0.0	0.0	0.0	0.0	0.0	0.0

Heating	Oil (MMBTU)	0.0	0.0	2.7	2.7	0.0	0.0	0.0	2.2
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	2.6	2.6	0.0	0.6
Heating	Electric (kWh)	14.4	14.4	15.2	15.2	14.4	14.4	266.3	15.0
Cooling	Electric (kWh)	45.2	0.0	45.2	0.0	45.2	0.0	45.2	1.9
	Total MMBtu	2.6	2.6	2.7	2.7	2.6	2.6	0.0	2.7
	Total kWh	59.6	14.4	60.4	15.2	59.6	14.4	311.5	16.9
	kW	0.1206	0.0164	0.1206	0.0173	0.1206	0.0164	0.3033	0.0171

Savings Type	Fuel	Multifamily New Construction							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Codes:		ADV1THERMFNC1	ADV1THERMFNC2	ADV1THERMFNC3	ADV1THERMFNC4	ADV1THERMFNC5	ADV1THERMFNC6	ADV1THERMFNC7	ADV1THERMFNC8
Heating	Natural Gas (MMBTU)	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	1.6	1.6	0.0	0.0	0.0	0.3
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	1.5	1.5	0.0	1.3
Heating	Electric (kWh)	8.5	8.5	8.9	8.9	8.5	8.5	147.8	8.6
Cooling	Electric (kWh)	44.2	0.0	44.2	0.0	44.2	0.0	44.2	2.6
	Total MMBtu	1.5	1.5	1.6	1.6	1.5	1.5	0.0	1.5
	Total kWh	52.8	8.5	53.1	8.9	52.8	8.5	192.0	11.2
	kW	0.1180	0.0100	0.1180	0.0104	0.1180	0.0100	0.1728	0.0100

Footnotes

[1] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home's thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[2] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. Efficiency Vermont will be exploring ways to better utilize this data once the program is underway and once the ENERGY STAR specification and program process is finalized.

[3] EVT applied 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours for 375 hours.

[4] Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis.

[5] Based on 2018-2020 Adv Thermostat Program participants. See "CUBE" tab in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[6] Estimate based on scaling national cooling prevalence in MF V SF (based on Table HC7.1 from RECS 2015) to the single family existing home cooling prevalence in 2018-2020 Advanced Thermostat Program participants. See tab 'HC7.1 2015' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[7] Estimate based on scaling national cooling prevalence in MF V SF (based on Table HC7.1 from RECS 2015) to the single family new construction cooling prevalence in 2018-2020 Advanced Thermostat Program participants. See tab 'HC7.1 2015' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[8] Based on review of # of thermostats per home data from Vermont Single-Family Existing Homes Onsite Report, 7/2018 and Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. See "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[9] Based on data from Table HC6.1 from 2009 EIA RECS showing number of thermostats in multi family buildings (note this information was not included in the 2015 RECS survey). See tab 'HC6.1 2009' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[10] Unknown value is based on TAG agreement 2017.

[11] This assumption accounts for market share of the two suppliers of Optimization (Nest and Ecobee), % of season that optimization is applied (where appropriate), % of customers assumed to opt in to the service and the %savings expected to be achieved. These assumptions will be reviewed regularly to ensure they continue to be a reasonable estimation. See "Optimization Assumptions" tab of "EVT Advanced Thermostat and Optimization 2020 Update.xls" for more details.

[12] This assumption is based upon the review of many evaluations from other regions in the US (see "Studies informing the TRM Savings Characterization for Advanced Thermostats.docx"). These sources, are from different regions, products, and program delivery designs, but collectively form a sound basis, and directional guidance for the existence and magnitude of cooling savings. Because cooling savings are more volatile than those for heating due to variables in control behaviors, population, and product factors, conservatism is warranted and 8% is considered a conservative estimate based upon the array of results from these studies. Further evaluation and regular review of this key assumption is encouraged.

[13] Savings of 8.8% for manual, and 5.6% for programmable thermostats as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value for existing buildings. The weighting of manual to programmable thermostats for when unknown is based upon Vermont Single-Family Existing Homes Onsite Report, 7/2018, 'Table 51 Type of Thermostat' for existing homes and data from Table HC6.1 from 2015 RECS.

[14] Used to estimate total cooling load of average house. Based on CAC capacity from Vermont Single-Family Existing Homes Onsite Report, 7/2018, Table 55 'Characteristics of Air Conditioning Systems, Statewide'.

[15] Estimate of multifamily cooling capacity is based on %adjustment of SF V MF relative cooling consumption data for the Northeast from Table CE3.2 of 2015 RECS multiplied by the single family capacity assumption. See tab 'CE.2 2015' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[16] Estimate is based upon calculation of average heating load from Vermont Single-Family Existing Homes Onsite Report, 7/2018. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[17] Estimate is based upon calculation of average heating load from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See "EVT Advanced Thermostat and Optimization 2020 Update.xls" for details.

[18] Multifamily per unit consumption is estimated using relative (single v multi family) space heating consumption data for the Northeast from Table CE3.2 of 2015 RECS multiplied by the Existing Homes consumption assumption. See tab 'CE.2 2015' in "EVT Advanced Thermostat and Optimization 2020 Update.xls".

[19] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference.

For boilers, fuel and electric use values were taken from Table 10.1, page 30 of James Lutz et al., Lawrence Berkeley Laboratory "Modeling energy consumption of residential furnaces and boilers in US homes". This was then weighted by furnace v boiler distribution to estimate an average value of 1.91%.

[20] Used to estimate total cooling load of average house. Based on CAC values from Vermont Single-Family Existing Homes Onsite Report, 7/2018, Table

55 'Characteristics of Air Conditioning Systems, Statewide'.

[21] Used to estimate total cooling load of average new construction house. Based on Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013.

[22] Vermont Single-Family Existing Homes Onsite Report, 7/2018, Table 40 using ACS data, percent of homes that are not natural gas, wood or other.

[23] Vermont Residential New Construction Homeowner Survey Report, 5/2018, Table 26. Percent of homes that are not natural gas, wood or other.

[24] Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Single-Family Existing Homes Onsite Report, 7/2018. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "EVT Advanced Thermostat and Optimization 2020 Update.xls" for details.

[25] Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "EVT Advanced Thermostat and Optimization 2020 Update.xls" for details.

[26] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[27] In contrast to program designs that utilize program affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation and other services, BYOT programs enroll customers *after* the time of purchase through online rebate and program integration sign-ups.

[28] Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

[29] Assumed to be $225 minus $75 for programmable thermostat.

ENERGY STAR Dehumidifiers

Measure Number: RS-HVC-DEHUM5 a
Portfolio: EVT TRM Portfolio 2019-12
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Efficient Products Program
End Use: HVAC

Update Summary

The existing dehumidifier measure for Time of Sale and Early Replacement ENERGY STAR qualified units is being revised to incorporate the latest standards, including new categories, as well as redefining existing ones.

Referenced Documents

- Federal appliance Efficiency standards from the code of federal regulations for dehumidifiers 10 CFR 430.32.v 1 &2
- ENERGY STAR Dehumidifiers V5 Program Specifications
- Dehumidifiers ENERGY STAR Most Efficient 2020 Proposed Criteria
- DOE Energy Conservation Standards for Dehumidifiers July 2012
- ENERGY STAR_Appliance_calculator_Dehumidifers_Last Updated 2016
- EVT Dehumidifer Analysis Nov 2019_Final

Description

A dehumidifier meeting the new minimum qualifying efficiency standard established by ENERGY STAR Program (Version 5.0), effective October 31, 2019, and ENERGY STAR Most Efficient 2020 Criteria, effective, 01/01/2020, is purchased and installed in a residential setting in place of a baseline unit. This measure applies to Time of Sale (Market Opportunity) and Early Replacement programs.

Program Type

Calculation Type: Time of Sale (Market Opportunity) and Early Replacement

Program Delivery / Implementation Type: Downstream and Free Product (Low Income Single-Family Voucher Program)

Baseline Efficiencies

Baseline efficiency is a dehumidifier that meets the Code of Federal Regulations appliance efficiency standards as defined below [1] :

	Product Capacity	Early Replacement Baseline Efficiency [2]	Time of Sale Baseline Efficiency[3]
Portable	(Pints/Day)	(L/kWh)	(L/kWh)
	≤25	≥1.35	≥1.30
	25.01 ≤ 50	≥1.43	≥1.60
	50.01 <155	≥1.93	≥2.80
Whole-Home	**Product Case Volume**	**Early Replacement Baseline Efficiency**[2]	**Time of Sale Baseline Efficiency**[3]
	(ft³)	(L/kWh)	(L/kWh)
	≤8	NA	≥1.77
	>8	NA	≥2.41

Efficient Equipment

High efficiency is defined as any model meeting or exceeding ENERGY STAR qualifying efficiency standard established by the current ENERGY STAR (Version 5.0). The Most Efficient Tier was included by ENERGY STAR and made effective on 01/01/2020. As defined by ENERGY STAR, a portable dehumidifier is designed to operate within the space without the attachment of additional ducting, although means may be provided for optional duct attachment. A whole-home dehumidifier is a unit designed to be incorporated into the home's HVAC system, or installed with its own duct system, and provide dehumidification for all conditioned spaces within the building enclosure.

Performance Criteria for ENERGY STAR Qualified Dehumidifiers:

	Product Capacity	ENERGY STAR Integrated Energy Factor	*Most Efficient* ENERGY STAR Integrated Energy Factor
Portable	*(Pints/Day)*	*(L/kWh)*	*(L/kWh)*
	≤25	≥1.57	≥1.70
	25.01 ≤ 50	≥1.80	≥1.90
	50.01 <155	≥3.30	≥3.40
Whole-Home	**Product Case Volume**	**ENERGY STAR Integrated Energy Factor**	***Most Efficient* ENERGY STAR Integrated Energy Factor**
	(ft³)	*(L/kWh)*	*(L/kWh)*
	≤8	≥2.09	≥2.22
	>8	≥3.30	≥3.40

Algorithms

Electric Demand Savings

ΔkW = ΔkWh/Hours

Symbol Table

Electric Energy Savings

ΔkWh = (((Avg Capacity × 0.473) / 24) × Hours) × (1 / (L/kWh_Base) – 1 / (L/kWh_Eff))

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	= Gross customer connected load kW savings
ΔkWh	=	= gross customer annual kWh savings for the measure
0.473	=	= Constant to convert Pints to Liters
24	=	= Constant to convert Liters/day to Liters/hour
Avg Capacity	=	= Average capacity of the unit (pints/day) = 38.4 [5]
Hours	=	= Run hours per year = 1632 [4]
L/kWh_Base	=	Baseline unit liters of water per kWh consumed, as provided in tables above Time of Sale, Portable = 1.54 [6]

Time of Sale, Whole-Home = 1.77 [6]

Early Replacement, Portable = 1.41 [2]

L/kWh_Eff = = Efficient unit liters of water per kWh consumed, as provided in tables above

ENERGY STAR, Portable = 1.76 [7]

ENERGY STAR Most Efficient: Portable = 1.86 [7]

ENERGY STAR, Whole-Home = 2.09 [8]

ENERGY STAR Most Efficient: Whole-Home = 2.22 [8]

Deemed Energy and Demand Savings

Time of Sale

Measure	Item Code	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)
ENERGY STAR: Portable	EPDEHUM	0.061	99
ENERGY STAR: Whole-Home	EPDEHUMW	0.094	153
ENERGY STAR Most Efficient: Portable	EPDEHUME2	0.085	139
ENERGY STAR Most Efficient: Whole-Home	EPDEHUME1	0.124	203

Early Replacement

Measure	Item Code	Remaining Life of Existing Unit		Remaining Measure Life		Mid-Life Savings Adjustment
		Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)	
ENERGY STAR: Portable	EPDEHUMER	0.106	172	0.061	99	58%
ENERGY STAR Most Efficient: Portable	EPDEHUMERME2	0.130	212	0.085	139	66%

Mid-Life Savings Adjustment

For the mid-life savings adjustment for the early replacement measure, please see the deemed energy and demand savings above.

Load Shapes

73a Residential - Dehumidifier

Net Savings Factors

Measures

ACEDEHUM	Energy Star Dehumidifier
ACEDHUME	ENERGY STAR Residential Dehumidifier Most Efficient tier

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6013EPEP [6032EPEP]	Efficient Products - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	ACEDEHUM	0.77	1.00
LISF Retrofit	6034LISF	ACEDEHUM	1.00	1.00
Efficient Products - Residential	6032EPEP	ACEDHUME	0.95	1.05
LISF Retrofit	6034LISF	ACEDHUME	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

The assumed measure life for a dehumidifier is 12 years, according to the ENERGY STAR Dehumidifier Calculator.

For early replacement, the remaining useful life of the existing unit is assumed to be 1/3 of the measure life, or 4 years.

Analysis period is the same as the lifetime.

Measure Cost

The incremental cost for the time of sale measure is the difference in cost between a baseline and an ENERGY STAR qualified unit. For early replacement measures the full cost of an ENERGY STAR unit is used. Please see the below table for cost assumptions.

TOS				Early Replacement			
Portable		Whole-Home		Portable		Whole-Home	
ENERGY STAR	ENERGY STAR Most Efficient	ENERGY STAR	ENERGY STAR Most Efficient	ENERGY STAR	ENERGY STAR Most Efficient	ENERGY STAR	ENERGY STAR Most Efficient
$10 [9]	$75[10]	$32 [11]	$75[10]	$523[12]	$588[12]	$1911[12]	$1976[12]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Footnotes

[1] The Federal Standard for Dehumidifiers changed as of June 2019; https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2

[2] Minimum 2012 Federal Standard Energy Factor. Federal efficiency standards for dehumidifiers manufactured between September 30, 2012 and June 13, 2019: 10 CFR 430.32.v.1. Weighted by capacity and equiment type based on available products on the ENERGY STAR Qualified Products List.

[3] Minimum 2019 Integrated Energy Factor. Federal appliance efficiency standards from the code of federal regulations for dehumidifiers manufactured on or after June 13, 2019. 10 CFR 430.32.v.2

[4] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator

[5] Average Water Removal Capacity (pints/day) from all units Energy Star QPL. Refer to Savings Calc tab of the analysis document: "EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx".

[6] Baseline Efficiency for smaller size Case Volume =< 8.0 ft^3. Refer to Savings Calc tab of analysis document: "EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx".

[7] Weighted average from Energy Star QPL. Refer to Savings Calc tab of analysis document: "EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx".

[8] ENERGY STAR Efficiency (L/kW) for smaller size Case Volume =< 8.0 ft^3. Refer to Savings Calc tab of analysis document: "EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx".

[9] Based on incremental costs from 2016 ENERGY STAR Appliance Calculator. Refer to weighted average calculation on Savings Calc tab of "EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx".

[10] DOE, Office of EERE, Appliance and Equipment Standards, Energy Conservation Standards for Residential Dehumidifiers, 10 CFR Part 430, July 23, 2012, page 73. The sourced table is an analysis on the incremental manufacturer production costs on dehumidifiers with varying incentive levels. Assuming the markup costs between the baseline units and the most efficient units are equal. The final incremental cost reproduced above is a straight average of all the dehumidifiers, both stand alone and whole house, with an efficiency level meeting or exceeding ENERGY STAR's Most Efficient criteria. Opted to combine the incremental cost into one value because the stand alone and whole house incremental costs were near idential.

[11] Based on incremental costs from 2016 ENERGY STAR Appliance Calculator. Refer to calculation of average on Savings Calc tab of "EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx".

[12] In order to derive the ENERGY STAR and ENERGY STAR Most Efficient capital equipment costs for the early replacement incremental costs, the time of sale incremental cost was added to the capital equipment cost of the baseline units. The baseline equipment costs are sourced from DOE Energy Conservation Standards for Residential Dehumidifiers, Appliance and Equipment Standard 10 CFR Part 430, July 23, 2012 (pg. 143-146) and weighted according to the available capacity units on the ENERGY STAR Qualified Products List.

Dehumidifier Recycling

Measure Number: RS-HVC-DEHUMREC a
Portfolio: EVT TRM Portfolio 2020-06
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Efficient Products Program
End Use: HVAC

Update Summary

New measure

Note: Created new measure codes and net savings factors for this measure. Copied the NSF from "ENERGY STAR Dehumidifiers".

Referenced Documents

- ENERGY STAR_Appliance_calculator_Dehumidifers_Last Updated 2016
- EVT Dehumidifer Analysis Nov 2019_Final
- Dehumidifier CFR_EERE-2012-BT-STD-0027-0045
- For Consumers _ Responsible Appliance Disposal (RAD) _US EPA
- NMR_CEE Eval_CT Appliance Retirement_Dec 2005
- US Code Title 42_2007 Energy Conservation Standards
- EVT_Dehumidifier Recycling_Analysis_Apr 2020_v2

Description

This measure involves the removal of an existing, inefficient, functioning dehumidifier from service prior to the end of its natural life (Early Retirement). Energy savings are based on the energy consumption of the retired dehumidifier during its estimated remaining life. However, the measure characterization also assumes a percentage of recycled dehumidifiers will ultimately be replaced. The energy consumption of this new unit, in place of the recycled unit, is taken into account in the savings estimate. If primary data indicate the unit is replaced forthright rather than retired/recycled, energy savings should be based on the Time of Sale 'ENERGY STAR Dehumidifier' measure.

Program Type

Calculation Type: Early Retirement

Program Delivery / Implementation Type: Downstream

Baseline Efficiencies

The baseline scenario is an existing, inefficient, functioning dehumidifier. The equipment efficiency is based on the unit meeting federal appliance efficiency standards at the date of manufacture, as detailed in the table below:

Product Capacity (pints/day)	Minimum 2007 Federal Standard Energy Factor (L/kWh)[1]	Minimum 2012 Federal Standard Energy Factor (L/kWh)[2]
≤ 25	1.00	1.35
> 25 and ≤ 35	1.20	1.35
> 35 and ≤ 45	1.30	1.50
> 45 and ≤ 54	1.30	1.60
> 54 and ≤ 75	1.50	1.70
> 75 and ≤ 185	2.25	2.50
Average[3]	1.38	1.60

Efficient Equipment

The efficient scenario is the removal of an existing dehumidifier from service. However, it is assumed that a percentage of units will be replaced, with the energy savings reduced in order to account for the consumption of these replacement units. These replacement units are assumed to meet the current federal appliance efficiency standards for dehumidifiers manufactured on or after June 13, 2019.[4]

Algorithms

Electric Demand Savings

$\Delta kW = (Capacity \times 0.473 / 24) \times ((1 / L\ per\ kWh_{Base}) - (\%\ Replaced \times (1 / L\ per\ kWh_{New})))$

Symbol Table

Electric Energy Savings

$\Delta kWh = (Capacity \times 0.473 \times Hours / 24) \times ((1 / L\ per\ kWh_{Base}) - (\%\ Replaced \times (1 / L\ per\ kWh_{New})))$

Symbol Table

Fossil Fuel Savings

Where:

% Replaced	=	Percent of units recycled that are replaced = 76%[5]
ΔkW	=	Gross customer connected load kW savings for a recycled dehumidifier.
ΔkWh	=	Gross customer annual kWh savings for a recycled dehumidifier.
0.473	=	Constant to convert pints to liters.
24	=	Constant to convert liters per hour to liters per day
Capacity	=	Average water removal capacity of the recycled dehumidifier in pints per day = 55.7 pints/day[3]
Hours	=	Average annual equipment run hours = 1,632 hours[6]
$L\ per\ kWh_{Base}$	=	Efficiency of the recycled dehumidifier in liters of water per kWh consumed, as provided in 'Baseline Efficiencies' table above. Values reflect a manufacture date range that coincides with timing of federal efficiency standards. = 1.38 L/kWh if unit manufactured before October 2012 = 1.60 L/kWh if unit manufactured between October 2012 and June 2019
$L\ per\ kWh_{New}$	=	Efficiency of replacement dehumidifier in liters of water per kWh consumed. = 2.18 L/kWh[4]

Deemed Energy and Demand Savings

Measure	Item Code	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)
Dehumidifer Recycling - Manufactured before October 2012	ACEDEHREC1	0.4128	674
Dehumidifer Recycling - Manufactured between October 2012 and June 2019	ACEDEHREC2	0.3034	495

Load Shapes

73a Residential - Dehumidifier

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
73	Residential - Dehumidifier	Active	15.9%	17.5%	31.7%	34.9%	0.0%	35.3%

Net Savings Factors

Measures

ACEDEHER	Dehumidifier Recycling

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	ACEDEHER	0.77	1.00

Lifetimes

The measure life is 5 years, which is the remaining measure life of the existing, recycled, dehumidifier.[7]

Measure Cost

The incremental cost for this measure is $73.57.

The incremental measure cost accounts for the cost to pick-up and recycle the existing dehumidifier plus a replacement cost to the customer for a new dehumidifier. The incremental cost also assumes the customers replacing their dehumidifier are deferring a future replacement cost they would have incurred on burn out of the equipment at the end of its useful life..

The estimated cost for recycling is $20[8]. The estimated cost for a replacement unit is $389.88, (which was calculated by multiplying the percentage of units assumed to be replaced, 76%, by the assumed cost of a standard efficiency unit, $513[9]). And the estimated lifecycle NPV of the future deferred replacement cost is calculated out to be $336.31.[10]

Footnotes

[1] The 2007 minimum federal appliance energy factor is sourced from federal appliance standards for dehumidifiers manufactured on or after October 1, 2007 (U.S. Code: Title 42 - Chapter 77 - Sub Chapter III - Part A - Section 6295).

[2] The 2012 minimum federal appliance energy factor is sourced from code of federal regulations for dehumidifiers manufactured on or after October 1, 2012 (10 CFR 430.32(v)).

[3] The average equipment efficiencies are soured from a weighted average of Efficiency Vermont rebated ENERGY STAR dehumidifiers, and the correlating baseline efficiency, based on the rebated unit's capacity. The average equipment capacity of 55.7 pints per day is based on this source as well. The EVT program data spans rebated dehumidifiers from January 2016 through mid-October 2019. For more detail, please see; "EVT_Dehumidifier Recycling_Analysis_Apr 2020_v2.xlsx"

[4] Code of Federal Regulations, appliance efficiency standards for dehumidifiers manufactured on after June 13, 2019 (10 CFR 430.32.(v)(2)). The average efficiency of the replacement dehumidifier is sourced from a weighted average of Efficiency Vermont rebated ENERGY STAR dehumidifiers based on the rebated unit's capacity.

[5] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Report states that 63% of room air conditioners are replaced with ENERGY STAR units and 13% with non-ENERGY STAR, for a total of 76% of units are replaced. Because this market research report was based on recycled room air conditioners, assumed identical replacement scenarios for this dehumidifer recycling measure. However, this formula assumes all are non-ENERGY STAR since the increment of savings between baseline units and ENERGY STAR units would be recorded by the Time of Sale, ENERGY STAR Dehumidifiers EVT measure when the new unit is purchased.

[6] Run hours per year is sourced from the ENERGY STAR Dehumidifier Calculator, which assumes 68 days of 24 hour operation.

[7] On average, turn-in units at the Cape Light Compact's May 2010 event were 7 years old. The full measure life for a dehumidifier of 12 years minus the average age of retired equipment of 7 years, equals a remaining life of 5 years. This is further corroborated by the Mass Save, Massachusetts Technical Reference Manual, October 2015.

[8] The estimated recycling cost is sourced from a quote from Recleim, which operates appliance recycling programs in other jurisdictions across the country.

[9] The estimated cost of a standard efficiency dehumidifier is sourced from the baseline capitol cost for the EVT ENERGY STAR Dehumidifier measure for a standard, non-ENERGY STAR unit. For contextual reference, the analysis file for that measure is included in the reference document section ("EVT_Dehumidifier_Analysis_Nov 2019_Final.xlsx"). It was deemed an appropriate source for the incremental cost for this measure because it is assumed that if a customer opts for their replacement dehumidifier to be an ENERGY STAR certified unit, they will be processed through EVT's program offerings, matching the incremental savings and incremental costs to the claimed metrics for that ENERGY STAR Dehumidifier measure.

[10] For more detail on the derivation of the incremental cost, please see: 'EVT_Dehumidifier Recycling_Analysis_Apr 2020_v2.xlsx

ENERGY STAR Residential Ventilation Fans, Non-Continuous

Measure Number: RS-HVC-ESRVF a
Portfolio: EVT TRM Portfolio 2020-01
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Referenced Documents

- ASHRAE 62.2 Section 4.1 Whole House Ventilation
- 2015 ICC VT Residential Building Energy Standards
- 2019 ENERGY STAR Certified Ventilating Fans for Bathroom/Utility Room List
- 2015 VT Energy Code Handbook_V4.1
- 2012_IECC_DOE_Residential Fan Efficiency
- 2007 GDS Associates Measure Life Report
- ENERGY STAR Ventilating Fans V4.1 Program Requirements
- ENERGY STAR Ventilating Fans Most Efficient 2020 Criteria V4.1
- EVT Bath Fan Analysis_Final
- Bath Fan_SST19 Results_Final

Description

This market opportunity is defined by the need for non-continuous mechanical ventilation for Exisiting Home retrofit projects. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2. An efficient bathroom ventilation fan must meet the qualifying efficiency standard established by ENERGY STAR Program (Version 4.1) and ENERGY STAR Most Efficient 2020 Criteria. This measure applies to the Low Income Single Family, Multifamily, and Existing Homes programs.

Program Type

Calculation Type: Market Opportunity: Time of Sale

Delivery Type: Direct Install

Algorithms

Electric Demand Savings

$\Delta kW = CFM \times (1/\eta_{Baseline} - 1/\eta_{Efficient})/1000$

$\Delta kW = CFM \times (1/\eta_{Baseline} - 1/\eta_{Most\ Efficient})/1000$

Symbol Table

Electric Energy Savings

$\Delta kWh = Hours \times \Delta kW$

Where:

ΔkW	=	Gross customer connected load kW savings per qualified ventilation fan and controls.
ΔkWh	=	Gross customer annual kWh savings per qualified ventilation fan and controls.
$\eta_{Efficient}$	=	Minimum Efficacy for ENERGY STAR fan, 2.8 CFM/Watt[1]
$\eta_{Baseline}$	=	Minimum Efficacy for Baseline fan, 1.4 CFM/Watt [2][3]
$\eta_{Most\ Efficient}$	=	Minimum Efficacy for Most Efficient ENERGY STAR fan, 10.0 CFM/Watt
CFM	=	Nominal Capacity of the exhaust fan, 50 CFM [4][5]
Hours	=	Assumed Annual Run Hours, 850 for non-continuous ventilation [6]

Baseline Efficiencies

Baseline efficiency is assumed to be the Minimum Vermont Residential Building Energy Code, which is 1.4 CFM/Watt.[2][3]

Efficient Equipment

New efficient criteria is assumed to be 2.8 CFM/Watt for ENERGY STAR Ventilating Bathroom Fans[1], and 10.0 CFM/Watt for ENERGY STAR Most Efficient Ventilating Bathroom Fans.

Load Shapes

10a Residential Ventilation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
10	Residential Ventilation	Active	31.7%	34.9%	15.9%	17.5%	32.2%	32.2%

Net Savings Factors

Measures

VNTXCEIL	Exhaust fan, ceiling

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	VNTXCEIL	1.00	1.00
LISF Retrofit	6034LISF	VNTXCEIL	1.00	1.00
Res Retrofit	6036RETR	VNTXCEIL	0.90	1.00

Lifetimes

19 years [7]

Analysis period is the same as the lifetime.

Measure Cost

Incremental cost per installed fan is $65.33 for quiet, efficient fans. [8] ENERGY STAR Most Efficient average cost per fan is approxiamtely $74.13[9]

Update Summary

	ΔkW	ΔkWh
ENERGY STAR, Efficient Vent Fan	0.018	15.19
ENERGY STAR, Most Efficient Vent Fan	0.031	26.12

[10]

Deemed Energy and Demand Savings

	ΔkW	ΔkWh
ENERGY STAR, Efficient Fan	0.018	15.19
ENERGY STAR, Most Efficient Fan	0.031	26.12

[10]

Footnotes

[1] Criteria for ENERGY STAR Certified Residential Ventilating Fans — Minimum Efficacy Levels. https://www.energystar.gov/products/heating_cooling/fans_ventilating/key_product_criteria

[2] 2015 ICC VT Residential Building Energy Standards, Chapter 4, Table R403.6.1 "Mechanical Ventilation System Fan Efficacy", page 30

[3] 2012_IECC_DOE_Residential Fan Efficiency, Table R403.5.1: Mechanical Ventilation System Fan Efficacy, page 7

[4] 2019 Berkley Lab, Residential Building Systems, citing ASHRAE Standard 62.2 https://homes.lbl.gov/ventilate-right/step-2-kitchen-and-bath-ventilation

[5] 2015 VT Energy Code Handbook, V4.1, Sec 3.1b

[6] EVT Bath Fan Analysis File, See sheet #1, "1_Calcs", using the Home Ventilating Institute's recommendation of minimum 20 minutes after each use. https://www.hvi.org/resources/publications/home-ventilation-guide-articles/how-much-ventilation-do-i-need/

[7] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.

[8] EVT Bath Fan Analysis File, See sheet #2, "2_EVT Data"

[9] EVT Bath Fan Analysis File, See sheet #3, "3_ESTAR_ME Cert"

[10] EVT Bath Fan Analysis File, See "1_Calcs"

ENERGY STAR Room A/C

Measure Number: RS-HVC-MEAC b
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Efficient Products Program
End Use: HVAC

Update Summary

Addition of standard ENERGY STAR level to downstream measure, consistent with ESRPP.

Referenced Documents

- epa-rpp-product-analysis-evt-2017
- GDS Associates_Measure Life Report_Jun 2007
- Coincidence Factor Study Room AC PUC NH
- Incremental_Cost_Recommendations_Non_Lighting_050917
- Room Air Conditioner ENERGY STAR Most Efficient 2020 Final Criteria
- evt-energy-star-room-ac-analysis-2020-xlsx
- doe-eere-2007-bt-std-0010-0050

Description

This measure involves the purchase and installation of a room air conditioning unit that meets the ENERGY STAR or ENERGY STAR Most Efficient requirements in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014. The measure depends on residential assumptions, but will also be available for commercial applications, but claim the same savings.

Program Type

Calculation Type: Time of Sale

Program Delivery/Implementation Type: Downstream

Baseline Efficiencies

The baseline assumption is a new room air conditioning unit that meets the Federal Standard (effective June 1st, 2014) efficiency standards as presented above.

Table 1: Baseline Efficiencies[1]

Product Type and Class (Btu/hr)		Federal Standard with louvered sides (CEER)	Federal Standard without louvered sides (CEER)
Without Reverse Cycle	< 8,000	11	10
	8,000 to 10,999	10.9	9.6
	11,000 to 13,999	10.9	9.5
	14,000 to 19,999	10.7	9.3
	20,000 to 27,999	9.4	9.4
	>=28,000	9	9.4
With Reverse Cycle	<14,000	9.8	9.3
	14,000 to 19,999	9.8	8.7
	>=20,000	9.3	8.7

Efficient Equipment

To qualify for this measure the new room air conditioning unit must either meet ENERGY STAR v4.1 specifications or ENERGY STAR Most Efficient (defined as outperforming the U.S. Department of Energy Federal Minimum Combined Energy Efficiency Ratio by at least 35% for models with a capacity >=14,000 Btu/hr and at least 25% for models with a capacity <14,000 Btu/hr).

Table 2: Efficient Equipment[2]

		ENERGY STAR	ENERGY STAR	ENERGY STAR Most Efficient	ENERGY STAR Most Efficient
Product Type and Class (Btu/hr)		With louvered sides (CEER)	Without louvered sides (CEER)	With louvered sides (CEER)	Without louvered sides (CEER)
Without Reverse Cycle	< 8,000	12.1	11.0	13.75	12.50
	8,000 to 10,999	12.0	10.6	13.63	12.00
	11,000 to 13,999	12.0	10.5	13.63	11.88
	14,000 to 19,999	11.8	10.2	14.45	12.56
	20,000 to 27,999	10.3	10.3	12.69	12.69
	>=28,000	9.9	10.3	12.15	12.69
With Reverse Cycle	<14,000	10.8	10.2	12.25	11.63
	14,000 to 19,999	10.8	9.6	13.23	11.75
	>=20,000	10.2	9.6	12.56	11.75

Algorithms

Electric Demand Savings

ΔkW = ΔkWh / EFLH

Symbol Table

Electric Energy Savings

ΔkWh = $\Delta kWh_{Weighted\ Average}$

ΔkWhClass = EFLH × Btu/hr × (1/$CEER_{base}$ - 1/$CEER_{ee}$))/1000

Where:

ΔkW	=	gross customer connected load kW savings for the measure. = 0.0759kW for ENERGY STAR = 0.3702kW for ENERGY STAR Most Efficient
ΔkWhClass	=	gross customer annual kWh savings for each capacity class
$\Delta kWh_{Weighted\ Average}$	=	gross customer weighted average annual kWh savings for the measure = 10.7 kWh for ENERGY STAR[4] = 52.2 kWh for ENERGY STAR Most Efficient[5]
Btu/hr	=	Capacity of rebated unit (Btu/hr)[6]
$CEER_{base}$	=	Combined Energy Efficiency Ratio of baseline unit Refer to Table 1 for Baseline Efficiencies
$CEER_{ee}$	=	Combined Energy Efficiency Ratio of ENERGY STAR Most Efficient unit Refer to Table 2 for Efficient Condition Criteria

EFLH	=	Full Load Hours of room air conditioning unit[3]
		141

Load Shapes

99b Room Air Conditioning

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
99	Room Air Conditioning	Active	0.7%	2.8%	53.3%	43.2%	0.0%	11.9%

Net Savings Factors

Measures

ACEESARP	Energy Star room AC

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6038VESH [is base track]	RNC VESH
6013EPEP [6032EPEP]	Efficient Products - Commercial

Lifetimes

The assumed measure life for a room air conditioner is 10.5 years[7].

Measure Cost

The incremental cost is assumed to be $50 for ENERGY STAR and $139 for ENERGY STAR Most Efficient[8].

Reference Tables

Based on deemed assumptions above:

Efficiency Level	ΔkWH	ΔkW	Measure Cost	Item Code
ENERGY STAR	10.7	0.0759	$50	ACEESRACENA0
ENERGY STAR MOST EFFICIENT	52.2	0.3702	$139	ACEESRACENA1

Footnotes

[1] Federal Standard effective June 1, 2014. Section 430.32 Title 10: Energy Subpart C—Energy and Water Conservation Standards. https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2

[2] See Room Air Conditioner ENERGY STAR Most Efficient 2020 Final Criteria

[3] Equivalent full load hours for Burlington, VT from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008. See 'Coincidence Factory Study Room AC PUC'.

[4] See 'epa-rpp-produc-analysis-evt-2017.xls' for weighting calculation.

[5] See 'evt-energy-star-room-ac-analysis-2020.xlsx' for both capacity specific calculations and weighted average.

[6] Representative capacities are provided in the corresponding spreadsheet files.

[7] Department of Energy, Office of Energy Efficency and Renewable Energy; "Energy Conservation Program, Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners", 10 CFR Part 430 (Docket: EERE-2007-BT-STD-0010, pg. 22514)

[8] ENERGY STAR is the estimate provided by ESRPP. ENERGY STAR Most Efficient is based on the weighted average of capacity/product bins from 2019 program data, see 'evt-energy-star-room-ac-analysis-2020.xlsx'.

Room Air Conditioner Recycling

Measure Number: RS-HVC-RACREC a
Portfolio: EVT TRM Portfolio 2020-06
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Efficient Products Program
End Use: HVAC

Update Summary

New measure

Note: Created new measure codes and net savings factors for this measure. Copied the NSF from "ENERGY STAR Most Efficient Room A/C".

Referenced Documents

- Coincidence Factor Study Room AC PUC NH
- ENERGY STAR Version 4.1 Specifications
- ENERGY STAR Room Air Conditioner Calculator
- DOE-EERE_2007-BT-STD-0010-0050
- EVT_Room AC_Analysis_Mar 2020
- For Consumers _ Responsible Appliance Disposal (RAD) _US EPA
- NMR_CEE Eval_CT Appliance Retirement_Dec 2005
- Room AC CFR_EERE-2014-BT-STD-0059-0001
- EVT_Room AC Recycling_Analysis_Apr 2020_v2

Description

This measure involves the removal of an existing, inefficient, functioning room air conditioner from service prior to the end of its natural life (Early Retirement). Energy savings are based on the energy consumption of the retired room air conditioner during its estimated remaining life. However, the measure characterization also assumes a percentage of recycled air conditioners will ultimately be replaced. The energy consumption of this new unit, in place of the recycled unit, is taken into account in the savings estimate. If primary data indicate the existing, recycled room air conditioner is replaced with a new ENERGY STAR qualifying unit, the savings increment between baseline and ENERGY STAR should be captured. The measure characterization assumes the program will target and retire room air conditioners manufactured and put into service prior to June 1, 2014.[1]

Program Type

Calculation Type: Early Retirement

Program Delivery / Implementation Type: Downstream

Baseline Efficiencies

The baseline scenario is an existing, inefficient, functioning room air conditioner. The equipment efficiency is based on the unit meeting federal appliance efficiency standards for a room air conditioner manufactured between October 1, 2000 and May 31, 2014[2], as detailed in the table below:

Product Class (Btu/h)		Federal Standard with louvered sides (EER_{Base})	Federal Standard without louvered sides (EER_{Base})
Without Reverse Cycle	< 8,000	9.7	9.0
	8,000 to 10,999	9.8	8.5
	11,000 to 13,999		8.5
	14,000 to 19,999	9.7	8.5
	20,000 to 24,999	8.5	8.5
	25,000-27,999	8.5	
	>=28,000		
With Reverse Cycle	< 14,000	N/A	8.5
	>= 14,000	N/A	8.0
	< 20,000	9.0	N/A
	>= 20,000	8.5	N/A

Casement	Federal Standard (EER_{Base})
Casement-only	8.7
Casement-slider	9.5

Efficient Equipment

The efficient scenario is the removal of an existing room air conditioner from service. However, it is assumed that a percentage of units will be replaced, with the energy savings reduced in order to account for these replacement units. These replacement units are assumed to meet the federal appliance efficiency standards for room air conditioners manufactured on or after June 1, 2014.[1]

Algorithms

Electric Demand Savings

ΔkW	= (Capacity x (1 / (EER_{Exist} x 1.01)) / 1000) - (% Replaced x (Capacity x (1 / $CEER_{New}$)) / 1000)

Symbol Table

Electric Energy Savings

ΔkWh	= (Hours x Capacity x (1 / (EER_{Exist} x 1.01)) / 1000) - (% Replaced x (Hours x Capacity x (1 / $CEER_{New}$)) / 1000)

Symbol Table

Fossil Fuel Savings

Where:

% Replaced	=	Percent of units recycled that are replaced = 76%[3]
ΔkW	=	Gross customer connected load kW savings
ΔkWh	=	Gross customer annual kWh energy savings
1.01	=	Factor to convert EER to CEER (CEER includes standy and off-power consumption)[4]
Capacity	=	Capacity in Btu/h of room air conditioner = 12,263 Btu/h[5]
$CEER_{New}$	=	Efficiency of replacement air conditioner = 10.3[6]
EER_{Exist}	=	Efficiency of existing, recycled air conditioner = 9.2[7]
Hours	=	Average annual equipment run hours = 141 hours[8]

Deemed Energy and Demand Savings

Measure	Item Code	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)
Room A/C Recycling	ACEESRACREC	0.4149	59

Load Shapes

99b Room Air Conditioning

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
99	Room Air Conditioning	Active	0.7%	2.8%	53.3%	43.2%	0.0%	11.9%

Net Savings Factors

Measures

ACEACREC	Room Air Conditioner Recycling

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	ACEACREC	0.67	1.33

Lifetimes

The measure life is estimated to be 3.5 years.[9]

Measure Cost

The incremental cost for this measure is $30.96.

The incremental measure cost accounts for the cost to pick-up and recycle the existing room air conditioner plus a replacement cost to the customer for a new room air conditioner. The incremental cost also assumes the customers replacing their room air conditioners are deferring a future replacement cost they would have incurred on burn out of the equipment at the end of its useful life.

The estimated cost for recycling is $20.[10] The estimated cost for a replacement unit is $129.20, (which was calculated by multiplying the percentage of units assumed to be replaced, 76%, by the assumed cost of a standard efficiency unit, $170[11]). And the estimated lifecycle NPV of the future deferred replacement cost is calculated out to be $118.24[12].

Footnotes

[1] Effective June 1, 2014 the Code of Federal Regulations released new appliance efficiency standards for room air conditioners manufactured on or after this date (10 CFR 430.32(b)).

[2] Federal appliance efficiency standards from the Code of Federal Regulations for room air conditioners manufactured between October 1, 2000 and May 31, 2014 (10 CFR 430.32(b)).

[3] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report." Report states that 63% of room air conditioners are replaced with ENERGY STAR units and 13% with non-ENERGY STAR, for a total of 76% of units are replaced. However, in order to be conservative, this formula assumes all are non-ENERGY STAR.

[4] Since the existing unit will be rated in EER, this factor is used to appropriately compare with the new CEER rating. Version 4.1 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See 'ENERGY STAR Version 4.1 Room Air Conditioners Program Requirements'.

[5] Average capacity of all units listed on the CEC Appliance Database, as accessed on 3/26/2018. For more detail, please see: "EVT_Room AC Recycling_Analysis_Apr 2020_v2.xlsx".

[6] Federal efficiency standards for room air conditioner manufactured after June 1, 2014: 10 CFR 430.32(b) - Weighted by capacity and equipment type based on available products on the CEC Appliance Database, as accessed on 3/26/2018.

[7] Federal efficiency standards for room air conditioner manufactured between October 1, 2000 and May 31, 2014: 10 CFR 430.32(b) - Weighted by capacity and equipment type based on available products on the CEC Appliance Database that are non-ENERGY STAR units, as accessed on 3/26/2018.

[8] Equivalent full load hours for Burlington, VT from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008. See 'Coincidence Factory Study Room AC PUC'.

[9] The measure life is assumed to be 1/3 of the full measure life of a room air conditioner, which is 10.5 years, as sourced from; Department of Energy, Office of Energy Efficency and Renewable Energy; "Energy Conservation Program, Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners", 10 CFR Part 430 (Docket: EERE-2007-BT-STD-0010, pg. 22514).

[10] The estimated recycling cost is sourced from a quote from Recleim, which operates appliance recycling programs in other jurisdictions across the country.

[11] The estimated cost of a standard efficiency room air conditioner is sourced from the baseline capitol cost for the EVT ENERGY STAR Room A/C measure for a standard, non-ENERGY STAR unit. For contextual reference, the analysis file for that measure is included in the reference document section ("EVT_Room AC_Analysis_Mar 2020.xlsx"). It was deemed an appropriate source for the incremental cost for this measure because it is assumed that if a customer opts for their replacement room air conditioner to be an ENERGY STAR or ENERGY STAR Most Efficient certified unit, they will be processed through EVT's program offerings, matching the incremental savings and incremental costs to the claimed metrics for those existing measures.

[12] For more detail on the derivation of the incremental cost, please see: 'EVT_Room AC Recycling_Analysis_Apr 2020_v2.xlsx'.

ENERGY STAR Room A/C

Measure Number: RS-HVC-ROOMAC b
Portfolio: EVT TRM Portfolio 2020-03
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Low Income Single Family
End Use: HVAC

Update Summary

New Measure. EVT has an existing room air conditioner measure that is specifically for ENERGY STAR's Emerging Tech qualified units. That measure details savings across multiple bins, based on product class and capacity. This measure is designed specifically for the emerging low income appliance voucher program that covers the entire cost of a room air conditioner. The program is designed to be implemented in the fashion that very little information will be collected and reported to EVT; so as a result, the energy savings for this measure is split into two bins, depending on the replacement scenario, and weighted across all product classes and capacities for any available ENERGY STAR unit. The measure details savings for early replacement and time of sale replacement scenarios.

03/2020 Update: Incorporated ENERGY STAR Most Efficient Criteria into the characterization.

Referenced Documents

- GDS Associates_Measure Life Report_Jun 2007
- Incremental_Cost_Recommendations_Non_Lighting_050917
- ENERGY STAR Version 4.1 Specifications
- Code of Federal Regulations_Room Air Conditioner
- ENERGY STAR Room Air Conditioner Calculator
- NEEP_CF Study Res Room AC_RLW Analytics_2008
- Room Air Conditioner ENERGY STAR Most Efficient 2020 Final Criteria
- DOE-EERE_2007-BT-STD-0010-0050
- EVT_Room AC_Analysis_Mar 2020

Description

This measure involves the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.1 or ENERGY STAR Most Efficient requirements. The measure is characterized specifically for the low income single-family voucher program, in which eligible customers will receiver a voucher that will cover the full cost of a new room air conditioner. The deemed savings for this program was aggregated and weighted due to the implementation of the program where collecting air conditioner type, capacity, and efficiency not possible. The savings are detailed for two replacement scenarios, early replacement and time of sale or market opportunity. The early replacement option will be used for customers opting in to the retailers offering of recycling the existing air conditioner. And the time of sale replacement option will be used if the customers opt out and an existing unit was not recycled by the purchasing retailer.

Program Type

Calculation Type: Time of Sale (Market Opportunity) and Early Replacement

Program Delivery / Implementation Type: Downstream and Free Product (Low Income Single-Family Voucher Program)

Baseline Efficiencies

Time of Sale (Market Opportunity): The baseline assumption is a new room air conditioning unit that meets federal efficiency standards for units manufactured on or after June 1, 2014 (10 CFR 430.32(b)). For more detail on the specifications based on product class and capacity, see Reference Tables.

Early Replacement: The baseline assumption for the remaining measure life is an existing, inefficient, functioning room air conditioning unit. The equipment efficiency is based on the unit meeting federal appliance efficiency stadards between October 1, 2000 and May 31, 2014.[1] After the remaining measure life, the baseline shifts to the Time of Sale (Market Opportunity) baseline; a new room air conditioning unit meeting current federal efficiency standards.

Efficient Equipment

The efficient equipment is a room air conditioner that meets the ENERGY STAR program requirements, version 4.1, effective October 26, 2015 or the 2020 ENERGY STAR Most Efficient criteria. For more detail on the specifications based on product class and capacity, see Reference Tables.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / EFLH

Symbol Table

Electric Energy Savings

ΔkWh	= EFLH x Capacity x (1 / $CEER_{Base}$ - 1 / $CEER_{EE}$) / 1000

Symbol Table

Fossil Fuel Savings
N/A

Where:

ΔkW	=	Gross customer connected load kW savings
ΔkWh	=	Gross customer annual kWh energy savings
Capacity	=	Capacity in Btu/h of room air conditioner = 12,263 Btu/h[3]
$CEER_{Base}$	=	Combined Energy Efficiency Ratio of baseline unit Time of Sale = 10.3[4] Early Replacement = 9.2[5]
$CEER_{EE}$	=	Combined Energy Efficiency Ratio of efficient unit ENERGY STAR = 11.4[6] ENERGY STAR Most Efficient = 13.3[7]
EFLH	=	Full Load Hours of room air conditioning unit = 141 hours[2]

Mid-Life Savings Adjustment

The mid-life savings adjustment for the early replacement scenario is:

- 44.6% for ENERGY STAR units
- 65.5% for ENERGY STAR Most Efficient units

Load Shapes

99b Room Air Conditioning

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW

99	Room Air Conditioning	Active	0.7%	2.8%	53.3%	43.2%	0.0%	11.9%

Net Savings Factors

Measures

ACEESARP	Energy Star room AC
ACEESAER	Energy Star room AC, early replacement

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LISF Retrofit	6034LISF	ACEESARP	1.00	1.00
LISF Retrofit	6034LISF	ACEESAER	1.00	1.00

Lifetimes

The assumed measure life for a room air conditioner is 10.5 years.[8] For early replacement, the remaining useful life of the existing unit is assumed to be 1/3 of the measure life, or 3.5 years.

Measure Cost

The incremental cost for the time of sale measure is assumed to be $50 for ENERGY STAR units and $133 for ENERGY STAR Most Efficient units. Incremental costs for time of sale measures represent the difference in costs between a baseline and an efficient unit.

For early replacement measures the full cost of an efficient unit is used, which is $220[9] for ENERGY STAR units and $303[10] for ENERGY STAR Most Efficient units.

O&M Cost Adjustments

N/A

Reference Tables

Deemed Energy and Demand Savings

Measure - Time of Sale	Item Code	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)
ENERGY STAR Room A/C Time of Sale	ACEESRACVOU	0.1149	16.2
ENERGY STAR Most Efficient Room A/C Time of Sale	ACEESRACVOU2	0.2688	37.9

Measure - Early Replacement	Item Code	Remaining Life of Existing Unit		Remaining Measure Life	
		Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)
ENERGY STAR Room A/C Early Replacement	ACEESRACVOUER	0.2574	36.3	0.1149	16.2
ENERGY STAR Most Efficient Room A/C Early Replacement	ACEESRACVOUER2	0.4106	57.9	0.2688	37.9

Code of Federal Regulations for Room Air Conditioners Manufactured After June 1, 2014 (Baseline, Time of Sale)

Product Class (Btu/h)		Federal Standard with louvered sides ($CEER_{Base}$)	Federal Standard without louvered sides ($CEER_{Base}$)
Without Reverse Cycle	< 8,000	11	10
	8,000 to 10,999	10.9	9.6
	11,000 to 13,999		9.5
	14,000 to 19,999	10.7	9.3
	20,000 to 24,999	9.4	9.4
	25,000-27,999	9	
	>=28,000		
With Reverse Cycle	< 14,000	N/A	9.3
	>= 14,000	N/A	8.7
	< 20,000	9.8	N/A
	>= 20,000	9.3	N/A

Casement	Federal Standard ($CEER_{Base}$)
Casement-only	9.5
Casement-slider	10.4

Code of Federal Regulations for Room Air Conditioners Manufactured Between October 1, 2000 and May 31, 2014 (Baseline, Early Replacement)

Product Class (Btu/h)		Federal Standard with louvered sides (EER_{Base})	Federal Standard without louvered sides (EER_{Base})
Without Reverse Cycle	< 8,000	9.7	9.0
	8,000 to 10,999	9.8	8.5
	11,000 to 13,999		8.5
	14,000 to 19,999	9.7	8.5
	20,000 to 24,999	8.5	8.5
	25,000-27,999	8.5	
	>=28,000		
With Reverse Cycle	< 14,000	N/A	8.5
	>= 14,000	N/A	8.0
	< 20,000	9.0	N/A
	>= 20,000	8.5	N/A

Casement	Federal Standard (EER_{Base})
Casement-only	8.7
Casement-slider	9.5

ENERGY STAR Qualifications for Room Air Conditioners (Efficient)

Product Class (Btu/h)		ENERGY STAR with louvered sides ($CEER_{EE}$)	ENERGY STAR without louvered sides ($CEER_{EE}$)
Without Reverse Cycle	< 8,000	12.1	11
	8,000 to 10,999	12	10.6
	11,000 to 13,999		10.5
	14,000 to 19,999	11.8	10.2
	20,000 to 24,999	10.3	10.3
	25,000-27,999		
	>=28,000	9.9	
With Reverse Cycle	< 14,000	N/A	10.2
	>= 14,000	N/A	9.6
	< 20,000	10.8	N/A
	>= 20,000	10.2	N/A

Casement	ENERGY STAR ($CEER_{EE}$)
Casement-only	10.5
Casement-slider	11.4

ENERGY STAR Most Efficient 2020 Qualifications for Room Air Conditioners (Efficient)

To qualify for this measure, the new room air conditioning unit must outperform the U.S. Department of Energy federal minimum combined energy efficiency ratio by:

- At least 35% for models with a capacity of >= 14,000 Btu/h
- At least 25% for models with a capacity of < 14,000 Btu/h

Product Class (Btu/h)		ENERGY STAR Most Efficient with louvered sides (CEER	ENERGY STAR Most Efficient without louvered sides (CEER
Without Reverse Cycle	< 8,000	13.75	12.50
	8,000 to 10,999	13.63	12.00
	11,000 to 13,999		11.88
	14,000 to 19,999	14.45	12.56
	20,000 to 24,999	12.69	12.69
	25,000-27,999		
	>=28,000	12.15	
With Reverse Cycle	< 14,000	12.25	11.63
	14,000 to 19,999	13.23	11.75
	>= 20,000	12.56	

Footnotes

[1] Federal appliance efficiency standards from the code of federal regulations for room air conditioners manufactured between October 1, 2000 and May 31, 2014 (10 CFR 430.32(b)).

[2] Equivalent full load hours for Burlington, VT from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

[3] Average capacity of all units listed on the CEC Appliance Database, as accessed on 3/26/2018. For more detail, please see: "EVT_Room AC_Analysis_Mar 2020.xlsx"

[4] Federal efficiency standards for Room A/C manufactured after June 1, 2014: 10 CFR 430.32(b) - Weighted by capacity and equipment type based on available products on the CEC Appliance Database, as accessed on 3/26/2018

[5] Federal efficiency standards for Room A/C manufactured between October 1, 2000 and May 31, 2014: 10 CFR 430.32(b) - Weighted by capacity and equiment type based on available products on the CEC Appliance Database, as accessed on 3/26/2018

[6] ENERGY STAR Program Requirements for Room A/C, version 4.1, effective October 26, 2015 - Weighted by capacity and equipment type based on available products on the CEC Appliance Database, as accessed on 3/26/2018

[7] ENERGY STAR Most Efficient 2020 Recognition Criteria for Room A/C - Weighted by capacity and equipment type based on available products on the CEC Appliance Database, as accessed on 3/26/2018

[8] Department of Energy, Office of Energy Efficency and Renewable Energy; "Energy Conservation Program, Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners", 10 CFR Part 430 (Docket: EERE-2007-BT-STD-0010, pg. 22514)

[9] Energy Star Room Air Conditioner Savings Calculator

[10] Incremental costs are sourced from the NEEP Mid-Atlantic TRM (version 9.0, October 2019) which uses hedonic models and data pulled from "2010-2012 WO017 Ex Ante Measure Cost Study", Itron, conducted on behalf of the California Public Utility Commission in 2014. For more information, please see EVT TRM document "Incremental_Cost_Recommendations_Non_Lighting_050917.xlsx" or analysis file associated with the EVT TRM measure "ENERGY STAR Most Efficient Room A/C" and the 'Costs' tab in "evt-energy-star-room-ac-analysis-xlsx". The derived incrmental costs were then weighted by capacity and equipment type based on available products on the CEC Appliance Database, as accessed on 3/26/2018. The Early Replacement cost (full equipment cost) was calculated by taking the cost of a baseline unit as sourced from the ENERGY STAR Room Air Conditioner Savings Calculator and adding the incremental cost of an ENERGY STAR Most Efficient unit.

Central Wood Pellet Boilers and Furnaces

Measure Number: VII-C-10 c
Portfolio: EVT TRM Portfolio 2018-02
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

Several assumptions have been updated in response to 2017 TAG discussions, revisions made to other measures during FY 2017, and updated cost information:

- %Elec and %Fuel for both residential and commercial buildings, to reflect updated Vermont market assessment reports
- nBase values for commercial buildings, to reflect the updated Vermont market assessment report for existing buildings and to match the updated Efficient Space Heating Systems measure for new construction
- Residential FLH values, to match a revised analysis based on VGS data
- The Commercial FLH value, calculated based on NY TRM FLH values and Vermont building data provided by Cadmus
- O&M and measure cost values, to reflect the 2016 version of the EIA "Updated Buildings Sector and Appliance and Equipment Costs and Efficiencies" report and to average costs for 2013 and 2020, and to reflect the percentage of fuel and heating system types from the updated Vermont market assessment reports
- The pellet wood penalty, to reflect that in 2018 and forward, in TEPF-funded programs, EVT is not counting the increased wood fuel use associated with biomass fuel switches from fossil fuels.

Referenced Documents

- US DOE, "Technical Support Document for Commercial Packaged Boilers", 2016.
- NEEP_EMV_EmergingTechResearch_Report_Final
- rerc-advanced-wood-pellet-system-eligible-equipment-inventory-vfy2016
- VT SF Existing Homes Onsite Report_final 021513
- VGS Usage Regression Work_04182017
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- NMR_Survey Analysis of Owners in Existing Homes in Vermont_Dec 2016
- EVT_Commercial EFLH_Analysis_July 2017
- EIA_Updated Buildings Sector Appliance and Equipment Costs and Efficiencies_Nov 2016
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018

Description

This measure applies to the installation by an approved contractor of a new central wood pellet boiler or furnace rated less than or equal to 340,000 Btu/h (< 100 kW) in new or existing, residential or commercial buildings. For installations in existing buildings or homes, it is assumed that the existing space heating system will remain in place and that the new pellet system will satisfy 90%[1] of the building's heating load.

Pellet systems must be installed according to manufacturer's recommendations and meet the following minimum efficiency and emissions requirements:

- 85% peak efficiency based on higher heating value (HHV) at full-load conditions
- <0.08 lb/MMBtu of particulate matter less than 2.5 microns ($PM_{2.5}$)

Baseline Efficiencies

The baseline is a blend of LP, oil, wood, and electric heating systems, based on the percentage of each system installed as a primary heating source in existing Vermont buildings for retrofits or in new Vermont buildings for new construction (NC).

Efficient Equipment

The new equipment must be a new central wood pellet boiler or furnace installed according to manufacturer's recommendations and meeting minimum efficiency and emissions requirements. For existing buildings, the new pellet system is assumed to satisfy 90% of the building's heating load.

In 2018 and forward, in TEPF-funded programs, EVT will not count the increased wood fuel use associated with biomass fuel switches from fossil fuels. Therefore, beginning in 2018 this measure does not apply a pellet heating penalty, except when the baseline is wood.

Algorithms

Electric Demand Savings

ΔkW_{Res} $= \Delta kWh_{Res}/FLH$

ΔkW_{Comm} $= \Delta kWh_{Comm}/FLH$

Symbol Table

Electric Energy Savings

The electric energy savings from the installation of a new pellet heating system in place of an electric heating system are described below.

See table below[5] for deemed electric energy and demand savings based on customer, building type, and equipment capacity.

Customer	Building Type	Equipment Capacity (Btu/hr)	ΔkWh	ΔkW
Residential	Existing	25,000 – 80,000	139.8	0.17910
		>80,000 – 150,000	256.7	0.32889
		>150,000 – 340,000	526.1	0.67406
	NC	25,000 – 80,000	477.7	0.72924
		>80,000 – 150,000	877.1	1.33915
		>150,000 – 340,000	1797.7	2.74460
Commercial	Existing	25,000 – 80,000	311.2	0.29307
		>80,000 – 150,000	571.6	0.53818
		>150,000 – 340,000	1171.4	1.10301
	NC	25,000 – 80,000	2751.0	2.59035
		>80,000 – 150,000	5051.7	4.75682
		>150,000 – 340,000	10353.6	9.74914

ΔkWh_{Res} $= FLH \times (Capacity / 1{,}000{,}000) / \eta_{Base, Electric} \times 293.071 \times \%Pellet \times \%Elec$

ΔkWh_{Comm} $= FLH \times (Capacity / 1{,}000{,}000) / \eta_{Base, Electric} / OF \times 293.071 \times \%Pellet \times \%Elec$

Symbol Table

Fossil Fuel Savings

The fuel savings from the installation of a new pellet heating system in place of an LP, oil, or wood heating system, the fuel penallties from the installation of a new pellet heating system in place of a wood heating system, and net savings are described below . The fuel savings for each fuel type are summed to create a blended fuel savings value.

See table below[12] for deemed fuel savings, penalties, and net savings based on customer, building type, and equipment capacity.

Customer	Building Type	Equipment Capacity (Btu/hr)	Heating System	$\Delta MMBtu_{Save}$ (by fuel type)	$\Delta MMBtu_{Save}$ (total savings before applying pellet penalty)	$\Delta MMBtu_{Penalty}$	$\Delta MMBtu_{Net}$ (total savings after applying pellet penalty)

Residential	Existing	25,000 – 80,000	LP	7.665	47.550	8.285	39.265
			Oil	28.878			
			Wood	11.007			
		>80,000 – 150,000	LP	14.076	87.318	15.214	72.105
			Oil	53.030			
			Wood	20.212			
		>150,000 – 340,000	LP	28.848	178.960	31.181	147.779
			Oil	108.686			
			Wood	41.425			
Residential	NC	25,000 – 80,000	LP	20.807	34.467	9.850	24.617
			Oil	2.319			
			Wood	11.341			
		>80,000 – 150,000	LP	38.209	63.295	18.088	45.207
			Oil	4.259			
			Wood	20.827			
		>150,000 – 340,000	LP	78.310	129.723	37.071	92.651
			Oil	8.728			
			Wood	42.684			
Commercial	Existing	25,000 – 80,000	LP	33.945	54.078	0.000	54.078
			Oil	20.133			
			Wood	0.000			
		>80,000 – 150,000	LP	62.336	99.307	0.000	99.307
			Oil	36.971			
			Wood	0.000			
		>150,000 – 340,000	LP	127.757	203.530	0.000	203.530
			Oil	75.772			
			Wood	0.000			
Commercial	NC	25,000 - 80,000	LP	23.728	25.256	1.327	23.929
			Oil	0.000			
			Wood	1.528			
		>80,000 – 150,000	LP	43.573	46.379	2.437	43.941
			Oil	0.000			
			Wood	2.806			
		>150,000 – 340,000	LP	89.302	95.053	4.995	90.058
			Oil	0.000			
			Wood	5.751			

$\Delta MMBtu_{Save, Res}$	$= \Delta MMBtu_{Save, Res, LP} + \Delta MMBtu_{Save, Res, Oil} + \Delta MMBtu_{Save, Res, Wood}$
$\Delta MMBtu_{Save, Res, LP}$	$= FLH \times (Capacity / 1{,}000{,}000) / \eta_{Base, LP} \times \%Pellet \times \%Fuel_{LP}$
$\Delta MMBtu_{Save, Res, Oil}$	$= FLH \times (Capacity / 1{,}000{,}000) / \eta_{Base, Oil} \times \%Pellet \times \%Fuel_{Oil}$
$\Delta MMBtu_{Save, Res, Wood}$	$= FLH \times (Capacity / 1{,}000{,}000) / \eta_{Base, Wood} \times \%Pellet \times \%Fuel_{Wood}$
$\Delta MMBtu_{Save, Comm}$	$= \Delta MMBtu_{Save, Comm, LP} + \Delta MMBtu_{Save, Comm, Oil} + \Delta MMBtu_{Save, Comm, Wood}$
$\Delta MMBtu_{Save, Comm, LP}$	$= FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{Base, LP} \times \%Pellet \times \%Fuel_{LP}$
$\Delta MMBtu_{Save, Comm, Oil}$	$= FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{Base, Oil} \times \%Pellet \times \%Fuel_{Oil}$
$\Delta MMBtu_{Save, Comm, Wood}$	$= FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{Base, Wood} \times \%Pellet \times \%Fuel_{Wood}$
$\Delta MMBtu_{Penalty, Res, Wood}$	$= FLH \times (Capacity / 1{,}000{,}000) / \eta_{Pellet} \times \%Pellet \times \%Fuel_{Wood}$
$\Delta MMBtu_{Penalty, Comm, Wood}$	$= FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{Pellet} \times \%Pellet \times \%Fuel_{Wood}$
$\Delta MMBtu_{Net, Res}$	$= \Delta MMBtu_{Save, Res} - \Delta MMBtu_{Penalty, Res, Wood}$
$\Delta MMBtu_{Net, Comm}$	$= \Delta MMBtu_{Save, Comm} - \Delta MMBtu_{Penalty, Comm, Wood}$

Where:

%Elec = Percentage of buildings assumed to have baseboard electric heating systems; see table below

Building Type	Customer Type	%Elec
Existing	Residential[6]	1%
	Commercial[7]	2%
New Construction	Residential[8]	17%
	Commercial[9]	62%

$\%Fuel_{LP}$ = Percentage of buildings assumed to use LP heating systems; see table below for %Fuel for each building, customer, and fuel type.

Building Type	Customer Type	Fuel Type	%Fuel
Existing	Residential[6]	LP	17%
		Oil	63%
		Wood	19%
	Commercial[7]	LP	62%
		Oil	36%
		Wood	0%
New Construction	Residential[8]	LP	54%
		Oil	6%
		Wood	24%
	Commercial[9]	LP	36%

		Oil	0%
		Wood	2%

$\%Fuel_{Oil}$ = Percentage of buildings assumed to use oil heating systems; see table within $\%Fuel_{LP}$ definition.

$\%Fuel_{Wood}$ = Percentage of buildings assumed to use wood heating systems; see table within $\%Fuel_{LP}$ definition.

%Pellet = Percentage of annual heating load provided by pellet system

= 90%[1] for existing buildings and 100% for NC

ΔkW_{Comm} = Gross customer annual connected load kW savings for the measure (commercial customers)

ΔkW_{Res} = Gross customer annual connected load kW savings for the measure (residential customers)

ΔkWh_{Comm} = Gross customer annual kWh savings for the measure (commercial customers)

ΔkWh_{Res} = Gross customer annual kWh savings for the measure (residential customers)

$\Delta MMBtu_{Net, Comm}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers) after subtracting the pellet penalty

$\Delta MMBtu_{Net, Res}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers) after subtracting the pellet penalty

$\Delta MMBtu_{Penalty, Comm, Wood}$ = Gross customer annual MMBtu fuel penalty for the measure (commercial customers) for pellet systems displacing wood space heating

$\Delta MMBtu_{Penalty, Res, Wood}$ = Gross customer annual MMBtu fuel penalty for the measure (residential customers) for pellet systems displacing wood space heating

$\Delta MMBtu_{Save, Comm, LP}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, LP baseline)

$\Delta MMBtu_{Save, Comm, Oil}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, oil baseline)

$\Delta MMBtu_{Save, Comm, Wood}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, wood baseline)

$\Delta MMBtu_{Save, Comm}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, total savings) before applying the pellet penalty

$\Delta MMBtu_{Save, Res, LP}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, LP baseline)

$\Delta MMBtu_{Save, Res, Oil}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, oil baseline)

$\Delta MMBtu_{Save, Res, Wood}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, wood baseline)

$\Delta MMBtu_{Save, Res}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, total savings) before applying the pellet penalty

η_{Pellet} = Efficiency of new pellet heating system, based on HHV

= 86%[13]

$\eta_{Base, LP}$ = Efficiency of baseline LP heating system; see table below for ηBase values based on building, customer, and fuel type.

Building Type	Customer Type	Fuel Type	η_{Base}
Existing	Residential[14]	Electric	100%
		LP	87.1%
		Oil	84.2%
		Wood	65%
	Commercial[15]	Electric	100%
		LP	88%
		Oil	84%
		Wood	65%
New Construction	Residential[16]	Electric	3.7 COP
		LP	93.8%
		Oil	86.3%
		Wood	75%
	Commercial[17]	Electric	3.5 COP
		LP	81%
		Oil	83%
		Wood	75%

$\eta_{Base, Electric}$ = Efficiency of baseline electric heating system; see table within $\eta_{Base, LP}$ definition.

$\eta_{Base, Oil}$ = Efficiency of baseline oil heating system; see table within $\eta_{Base, LP}$ definition.

$\eta_{Base, Wood}$ = Efficiency of baseline wood heating system; see table within $\eta_{Base, LP}$ definition.

1,000,000 = Factor to convert Btu/hr to MMBtu/hr

293.071 = Factor to convert MMBtu to kWh

Capacity = Output capacity (Btu/hr) of new pellet boiler or furnace; see table below for default capacity based on capacity bin[10]

Capacity Bin	Default Capacity (Btu/hr)
25,000 – 80,000	55,000
>80,000 – 150,000	101,000
>150,000 – 340,000	207,000

FLH = Estimated average full load heating hours; see table below

Customer Type	Building Type	FLH
Residential	Existing[2]	780
	New Construction[3]	655
Commercial[4]	Existing and New Construction	1,062

OF = Oversize factor: ratio of heating unit size to actual heating load

= 1.1[11]

Load Shapes

5b Residential Space heat

17b Commercial Space Heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW

5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%
17	Commercial Space Heat	Active	43.2%	52.3%	1.6%	3.0%	17.9%	0.6%

Net Savings Factors

Measures

SHFBBIOM	Biomass Fuel Switch

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013PRES [is base track]	Pres Equip Rpl
6036RETR [is base track]	Res Retrofit
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	SHFBBIOM	0.79	1.00
Pres Equip Rpl	6013PRES	SHFBBIOM	0.80	1.00
Res Retrofit	6036RETR	SHFBBIOM	0.80	1.00
6014PRES	6014PRES	SHFBBIOM	0.80	1.05

Lifetimes

The expected measure life is assumed to be 20 years.[18]

Measure Cost

For existing buildings, the measure cost is the cost of installation (labor and equipment) for a pellet boiler or furnace: $20,000.[19]

For new construction, the measure cost is the incremental full installation cost difference (labor and equipment) between a new LP, oil, wood, or electric heating system and a new, qualifying pellet heating system. See table below for costs related to new construction.

Customer	Measure Cost
Residential[20]	$13,322
Commercial[21]	$11,764

O&M Cost Adjustments

For existing buildings, the annual O&M cost is the incremental O&M cost difference between LP, oil, wood, or electric heating systems and a blended assumption of 90% pellet heat and 10% LP, oil, wood, or electric resistance heat.

For new construction, the annual O&M cost is the incremental O&M cost difference between LP, oil, wood, or electric heating systems and 100% pellet heat.

Annual O&M costs for pellet boilers and furnaces are assumed to be $250.[22] See table below for O&M cost adjustments, which represent a penalty (increase in costs).

Customer	Building Type	O&M Cost Adjustment
Residential	Existing[23]	$122
	NC[24]	$141
Commercial	Existing[25]	$159
	NC[26]	$156

Footnotes

[1] Energy & Research Solutions, "Emerging Technologies Research Report," (report prepared for the Regional Evaluation, Measurement, and Verification Forum, February 13, 2013): page 9-22.

[2] Residential FLH for existing homes is a weighted average of FLH for boilers and furnances in existing homes. Boiler and furnace weightings are from NMR Group, "VT SF Existing Homes Onsite Report," 2013, Table 5-4. FLH values were estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis.

[3] Residential FLH for new construction is a weighted average of FLH for boilers and furnances in new homes. Boiler and furnace weightings from page 47, Table 47, NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017. Combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps removed. Values for Efficiency Vermont used. FLH values were estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. See 'VGS Usage Regression Work_04182017.xls' for analysis. FLH values were estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. See 'VGS Usage Regression Work_04182017.xls' for analysis.

[4] Commercial FLH is a weighted average of commercial FLH values from New York Joint Utiliites,"New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (Version 4)," April 29, 2016 and Vermont building data provided by Cadmus. See file EVT_Commercial EFLH_Analysis_July 2017.xlsx for calculation details.

[5] For electric energy and demand calculations, see file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[6] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)," December 5, 2016: page 29, Table 38 (Efficiency Vermont data). Natural gas, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump." Percentage of cordwood (versus pellets) estimated as 15%. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[7] Percentage of heating system fuel types in existing Vermont commercial buildings based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 63, Figure 46 (Efficiency Vermont data). Natural gas, "unknown," and "other" heating systems were excluded. Percentage of electric resistance heating systems estimated at 1% based on Figure 47. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[8] Percentage of heating system fuel types in new residential buildings in Vermont based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017: page 45, Table 46 (Efficiency Vermont data). Natural gas and pellets excluded. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[9] Percentage of heating system fuel types in new Vermont commercial buildings based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 177, Figure 128 (Efficiency Vermont data). Natural gas and "unknown," heating systems were excluded. The report states that "other" is made up primarily of wood-fired boilers, but according to the raw data provided by Cadmus to Efficiency Vermont, 2 of the 4 systems in this category are pellet systems. These 2 systems were removed from the analysis. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[10] Based on pellet system models available from Renewable Energy Resource Center, "Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Pellet Heating System Eligible Equipment Inventory," June 6, 2016. See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for capacity bin calculations.

[11] Oversizing factor determined from US Department of Energy, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers," March 4, 2016: pages 7-3 and 7-10. Oversizing Factor = 1.1; 10% larger unit than required "based on typical sizing practices."

[12] For fossil fuel savings calculations, see file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[13] Weighted average efficiency of qualified models available on Renewable Energy Resource Center, "Small Scale Renewable Energy Incentive Program

(SSREIP) Advanced Wood Pellet Heating System Eligible Equipment Inventory," June 6, 2016.

[14] Efficiencies for existing residential LP and oil heating systems are a weighted average based on the percentage of boilers and furnaces used as single major heating system in existing Vermont homes, from NMR Group, "Vermont Single-Family Existing Homes Onsite Report," February 15, 2013: pages 58-61, Tables 5-4, 5-8 and 5-9. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx. Pellet systems in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of existing wood heating systems based on professional judgment.

[15] Efficiencies for existing commercial LP and oil heating systems are a weighted average based on heating system data from Figure 47, and boiler and furnace efficiencies from Table 15: Cadmus, "2016 VT Business Sector Market Characterization and Assessment Study," April 2017. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx. Pellet systems in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of existing wood heating systems based on professional judgment.

[16] Efficiencies for new residential electric, LP, and oil heating systems are based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Boiler, furnace, and heat pump weightings are from page 47, Table 47, and equipment efficiencies are rom pages 49-50, Tables 50-52, NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Oil boilers, combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps were removed from boiler and furnace weighting calculations. Values for Efficiency Vermont used. nBase (LP) is a weighted average based on the percentage of LP boilers and furnaces installed in new Vermont homes. Nbase (oil) is the efficiency of oil boilers.See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx. Efficiency of new wood heating systems based on professional judgment.

[17] Efficiencies for new commercial LP and oil heating systems are an average of efficiencies for boilers <300,000 Btu/hr and furnaces <225,000 Btu/hr. Lowest efficiency available from AHRI database, except for oil furnaces <225 MBH and LP boilers <300 MBh, which were adjusted upward to better reflect the efficiencies available within those capacity bins. See reference file AHRI Boiler and Furnace Data.xlsx. Efficiency of existing wood heating systems based on professional judgment.

[18] Pellet boiler and furnace lifetime from Energy & Research Solutions, "Emerging Technologies Research Report," (report prepared for the Regional Evaluation, Measurement, and Verification Forum, February 13, 2013): page 9-20.

[19] Pellet boiler installed cost from Energy & Research Solutions, "Emerging Technologies Research Report," (report prepared for the Regional Evaluation, Measurement, and Verification Forum, February 13, 2013): page 9-2. Pellet furnace installed costs are assumed to be similar to pellet boiler costs.

[20] The baseline full installation cost for residential NC is based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and pellet systems excluded. Full installation costs for baseline heating systems, except for cordwood furnaces, are the average of typical residential costs for years 2013 and 2020 from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood furnaces are assumed to cost the same as pellet furnaces ($20,000). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for measure cost calculations.

[21] The baseline full installation cost for commercial NC is based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 178, Figure 129 ("All" data) and page 181, Figure 131. Boilers are divided between propane (44%) and wood (14%), and it is assumed that all furnaces are propane-fired. Full installation costs for baseline heating systems, except for cordwood boilers, are the average of typical residential costs for years 2013 and 2020 from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood boilers are assumed to cost the same as pellet boilers ($20,000). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for measure cost calculations.

[22] Pellet furnace and boiler O&M costs are assumed to be approximately the same as O&M costs for pellet stoves from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016.

[23] The baseline O&M cost for existing homes is based on the percentage of each fuel type in existing Vermont homes. LP and oil systems are divided between boilers and furnaces. It is assumed that all wood heating systems are cordwood stoves. O&M costs for baseline heating systems, except for electric resistance, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

[24] The baseline O&M cost for residential NC is based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and pellet systems excluded. O&M costs for baseline heating systems, except for cordwood furnaces, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood furnace costs are assumed to be the same as costs for pellet boilers ($250). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

[25] The baseline O&M cost for existing buildings is based on the percentage of each fuel type in existing Vermont buildings. LP and oil systems are divided between boilers and furnaces. O&M costs for baseline heating systems, except for cordwood boilers and electric resistance, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

[26] The baseline O&M cost for commercial NC is based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 178, Figure 129 ("All" data) and page 181, Figure 131. Boilers are divided between propane (44%) and wood (14%), and it is assumed that all furnaces are propane-fired. O&M costs for baseline heating systems, except for cordwood boilers, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood boiler costs are assumed to be the same as costs for pellet boilers ($250). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

Air to Water Heat Pump

Measure Number: VII-C-14 c
Portfolio: EVT TRM Portfolio 2020-06
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

Expanded the bin allocations for this measure from 2, 3, and 4+ ton bins to 2, 3, 4, 5, and 6 ton bins

Referenced Documents

- NEEP Incremental Cost Study Report 2011
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- VT SF Existing Homes Onsite Report - DRAFT 122117
- New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016
- GDS Associates_Measure Life Report_Jun 2007
- NEEP Incremental Cost Study Phase II_Jan 2013
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- NREL_Optimizing Hydronic System Performance_Oct 2013
- EVT_Air to Water Heat Pump Analysis_v11

Description

This measure claims savings for the installation of an air to water heat pump. Heating savings are claimed on the home's auxiliary fossil fuel hydronic heating system and accounts for the fossil fuel system providing supplemental heat at low outdoor air temperatures. The electric penalty is the result of the air to water heat pump operating in heating mode, down to 0°F outdoor air temperature, at which point the auxiliary heating system assumes the full heating load.

The heat pump extracts low temperature heat from outside air and transfers it to a fluid steam to be used by a hydronic distribution system. The characterization assumes a standard mode of operation regardless of installation, location, or application – residential or commercial. The installed air to water heat pump is intended to supplement the existing fossil fuel heating system and not completely replace it, and the characterization of this measure assumes a midstream program delivery method.

Air to water heat pumps are categorized as low temperature hydronic heating systems and typically operate at a maximum supply water temperature of 120°F. If an air to water heat pump is retrofitted on an existing high temperature hydronic fossil fuel system, additional emitters are required in order to meet the design load of the building. The minimum qualification criteria for an air to water heat pump is to generate 110°F supply water at an outdoor temperature of 5°F with a COP of 1.7 or greater.

Program Type

Calculation Type: Time of Sale (Market Opportunity) and Retrofit

Program Delivery / Implementation Type: Midstream

Baseline Efficiencies

For retrofit replacement scenarios, the baseline condition is assumed to be the existing fossil fuel hydronic heating system. For market opportunities, the baseline condition is assumed to be a code compliant fossil fuel hydronic heating system. Sites with natural gas fossil fuel systems are excluded from participation in this measure and as a result, are not included in the characterization.

Table 1 - Residential Baseline Efficiency

Replacement Scenario	Equipment Fuel Type	Average Boiler Efficiency
RET[1]	Fuel Oil	83.6%
	Propane	87.8%
	Wood	65.0%
MOP[2]	Fuel Oil	86.3%
	Propane	93.4%
	Wood	75.0%

Table 2 - Commercial Baseline Efficiency

Replacement Scenario	Equipment Fuel Type	Average Boiler Efficiency
RET[3]	Fuel Oil	85.0%
	Propane	87.0%
	Wood	65.0%
MOP[4]	Fuel Oil	80.0%
	Propane	80.0%
	Wood	75.0%

Efficient Equipment

The installed heat pump is assumed to meet the efficiency outlined in table 3, which represents the average efficiency of qualifying equipment used in the energy savings algorithm. The values in the following table are a result of weighted averages of available equipment from local distributors binned across Burlington, VT weather data down to an outdoor air temperature of 0°F, averaged across 100°F, 110°F, and 120°F supply water temperatures.

Table 3 - Residential and Commercial Air to Water Heat Pump Efficiency

Equipment	Rating Heating Capacity (Tons)	COP
Air to Water Heat Pump	2.0	2.75
	2.5	2.76
	3.0	2.78
	3.5	2.90
	4.0	3.03
	4.5	2.87
	5.0	2.71
	5.5	2.80
	6.0	2.89
	Overall Average	2.83

Algorithms

Electric Demand Savings

Given the primary impact is on heating, demand impact is characterized for heating and as a penalty (increase in electric consumption).

$\Delta kW_{Penalty}$	$= \Delta kWh_{Penalty} / EFLH$

Symbol Table

Electric Energy Savings

$\Delta kWh_{Penalty}$	$= kBtuh \times (-1/(COP \times 3.412)) \times EFLH$

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= (kBtuh / 1000) x EFLH x (1/AFUE)

Where:

$\Delta kW_{Penalty}$	=	Total average winter coincident peak kW increase (deemed assumption for prescriptive)
$\Delta kWh_{Penalty}$	=	Gross customer electric energy penalty (deemed assumption for prescriptive)
ΔMMBtu	=	MMBtu savings for each fuel type (deemed assumption for prescriptive)
AFUE	=	Annual Fuel Utilization Efficiency; the efficiency of the fossil fuel heating system (see tables 1 and 2 for more detail)
COP	=	Coefficient of Performance for the installed air to water heat pump (see table 3 for more detail)
EFLH	=	Equivalent full load heating hours = 1,626 hours (residential)[7] = 1,062 hours (commercial)[8]
kBtuh	=	Average rated heating capacity (see table 5 for more detail as the average rated heating capacity varies over the different bin sizes)[9] = 39.14 kBtu/h

Table 4 - Boiler Fuel Type Distribution[5]

Replacement Scenario	Fuel Type	Residential	Commercial
RET	Fuel Oil	56.2%	46.8%
	Propane	39.6%	53.2%
	Wood	4.2%	0.0%
MOP	Fuel Oil	14.8%	0.0%
	Propane	74.1%	75.9%
	Wood	11.1%	24.1%

Table 5 - Deemed Energy Savings Summary[6]

Sector	Rated Heating Capacity (Tons)	Rated Heating Capacity Range (Tons)	Average Rated Heating Capacity (kBtu/h)	ΔkWh	ΔkW	ΔMMBtu_Oil	ΔMMBtu_LP	ΔMMBtu_Wood
Residential	2.0	≥ 2.0 and < 2.5	25,833	-4,473	-2.7511	17.7	26.1	4.5
	2.5	≥ 2.5 and < 3.0	29,495	-5,083	-3.1262	20.2	29.8	5.1
	3.0	≥ 3.0 and < 3.5	33,157	-5,693	-3.5013	22.8	33.5	5.7
	3.5	≥ 3.5 and < 4.0	40,371	-6,595	-4.0561	27.7	40.8	7.0
	4.0	≥ 4.0 and < 4.5	47,584	-7,497	-4.6109	32.7	48.1	8.2
	4.5	≥ 4.5 and < 5.0	46,644	-7,770	-4.7786	32.0	47.2	8.0
	5.0	≥ 5.0 and < 5.5	45,704	-8,042	-4.9463	31.4	46.2	7.9
	5.5	≥ 5.5 and < 6.0	48,291	-8,216	-5.0531	33.2	48.8	8.3
	6.0	≥ 6.0	50,877	-8,390	-5.1599	34.9	51.4	8.8
Commercial	2.0	≥ 2.0 and < 2.5	25,833	-2,922	-2.7511	11.6	32.8	6.8
	2.5	≥ 2.5 and < 3.0	29,495	-3,320	-3.1262	13.2	37.4	7.7
	3.0	≥ 3.0 and < 3.5	33,157	-3,718	-3.5013	14.8	42.1	8.7
	3.5	≥ 3.5 and < 4.0	40,371	-4,308	-4.0561	18.1	51.2	10.6
	4.0	≥ 4.0 and < 4.5	47,584	-4,897	-4.6109	21.3	60.3	12.4
	4.5	≥ 4.5 and < 5.0	46,644	-5,075	-4.7786	20.9	59.2	12.2
	5.0	≥ 5.0 and < 5.5	45,704	-5,253	-4.9463	20.4	58.0	12.0
	5.5	≥ 5.5 and < 6.0	48,291	-5,366	-5.0531	21.6	61.2	12.6
	6.0	≥ 6.0	50,877	-5,480	-5.1599	22.8	64.5	13.3

Load Shapes

5b Residential Space heat
17b Commercial Space Heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%
17	Commercial Space Heat	Active	43.2%	52.3%	1.6%	3.0%	17.9%	0.6%

Net Savings Factors

Measures

SHFDAWHP	Air to water heat pump - Fuel-fired Baseline

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032UPST [6032EPEP]	Upstream - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	SHFDAWHP	1.00	1.00

Lifetimes

The expected measure life is assumed to be 18 years.[10]

Measure Cost

The incremental cost is based on the rated heating capacity and replacement scenario, as detailed in table 6 below.

For market opportunity replacement scenarios, the incremental cost is based on an average of equipment list prices supplied by local distributors plus an additional $1,336[11], which is the estimated cost of low temperature hydronic emitters. If an air to water heat pump is retrofitted on an existing high temperature hydronic fossil fuel system, additional emitters are required in order to meet the design load of the building. The added costs of the emitters is assumed in both the market opportunity and the retrofit scenario. It is included in the market opportunity costs because the baseline assumption is a code compliant high temperature fossil fuel hydronic heating system and the low temperature emitters represent an added cost to facilitate the low temperature requirements of the air to water heat pump.

For retrofit replacement scenarios, the incremental cost assumes an additional installation cost of $1,315[12].

Table 6 - Incremental Costs

Rated Heating Capacity (Tons)	Retrofit Incremental Costs	Market Opportunity Incremental Costs	Overall Incremental Costs[6]
2.0	$6,404	$5,089	$5,746
2.5	$7,326	$6,012	$6,669
3.0	$8,248	$6,934	$7,591
3.5	$9,224	$7,909	$8,566
4.0	$10,199	$8,884	$9,542
4.5	$11,116	$9,801	$10,459
5.0	$12,033	$10,718	$11,376
5.5	$12,971	$11,657	$12,314
6.0	$13,909	$12,595	$13,252

Reference Tables

Table 7 - Item Codes

Sector	Rated Heating Capacity (Tons)	Item Codes
Residential	2.0	RES-AWHP-2
	2.5	RES-AWHP-2.5
	3.0	RES-AWHP-3
	3.5	RES-AWHP-3.5
	4.0	RES-AWHP-4
	4.5	RES-AWHP-4.5
	5.0	RES-AWHP-5
	5.5	RES-AWHP-5.5
	6.0	RES-AWHP-6
Commercial	2.0	COM-AWHP-2
	2.5	COM-AWHP-2.5
	3.0	COM-AWHP-3
	3.5	COM-AWHP-3.5
	4.0	COM-AWHP-4
	4.5	COM-AWHP-4.5
	5.0	COM-AWHP-5
	5.5	COM-AWHP-5.5
	6.0	COM-AWHP-6

Footnotes

[1] Based on the average findings from the, "Vermont Single-Family Existing Homes Onsite Report, Draft", NMR Group, Inc., December 2017 (page 44). As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

[2] "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits", NMR Group, Inc., May 12, 2017 (pages 49-50). The efficiency of natural gas and propane boilers was combined and not included separately in the report. In order to incorporate the propane fuel type into the analysis, opted to use the combined efficiency values for observed natural gas and propane boilers. As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

[3] Mean observed efficiency for boilers for existing commercial buildings, as sourced from; "2016 Vermont Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). The efficiency of natural gas and propane boilers was combined and not included separately in the report. In order to incorporate the propane fuel type into the analysis, VEIC opted to use the combined efficiency values for observed natural gas and propane boilers. As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

[4] Minimum efficiency requirements for gas- and oil-fired boilers <300,000 Btu/h, as sourced from the 2015 VT Commercial Building Energy Standards (CBES). As the efficiency of wood boilers is not governed in code compliance, the value is based on professional judgement.

[5] As the program delivery method for this measure is midstream, the intention is the fuel type of the boiler being off-set will be unknown, and this necissitates a fuel type distribution of boilers being impacted by this measure. The MMBtu energy savings are thus split across the different fuel types based on their saturation in the state of Vermont and is dependant on the building stock and sector. Sites utilizing natural gas fuel are excluded from participating in this measure and are removed from consideration in this characterization. The derivation for the fuel type distribution and the accompanying sources can be viewed in detail in the "EVT_Air to Water Heat Pump Analysis_v11.xlsx"

[6] Due to the implementation of this measure through a midstream delivery mechanism, the actual replacement scenario (retrofit vs. market opportunity) will be unknown. As a result, the energy savings and incremental costs for the two replacement options were aggregated based on an assumption that 50% of installs will be retrofits.

[7] Residential EFLH is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating system provides heating below 57.5°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of 0°F. The analysis assumes the heat pump provides heating based on its rated capacity up to the estimated load.

[8] The commercial EFLH is sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

[9] The equipment capacity is sourced as a weighted average of available equipment from local manufacturers, rated at varying outdoor air temperatures and supply water temperatures, and binned across Burlington, VT weather data down to an outdoor air temperature of 0°F at specified load conditions. For more information on its derivation, please see: "EVT_Air to Water Heat Pump Analysis_v11.xlsx". The half-ton increment capacitity equipment, operating conditions, efficiencies, and energy savings are interpolated based on the whole number-increment equipment.

[10] The measure life is assumed to be similar to the measure life for an air source heat pump. While boilers and other hydronic heating systems will typically have measure lives exceeding 20 years, as a conservative estimate, the measure life for an air source heat pump was sourced from "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.

[11] "Optimizing Hydronic System Performance in Residential Applications", NREL, October 2013 (page 8). The cost of low temperature hydronic emitters represents a straight average of the three efficiency scenarios incremental costs' that were modeled in the report.

[12] The installation cost is sourced from estimates of two local manufacturers who compared the installation of air to water heat pumps to that of; (1) multi-head mini-split heat pumps, and (2) low temperature condensing boilers. As a result, the estimated installation cost for these two measures was sourced from NEEP Incremental Cost Studies ($893 for a boiler and $1,736 for a multi-head mini-split heat pump) and averaged accordingly.

Brushless Permanent Magnet (BLPM) Circulator Pump

Measure Number: VII-C-3 d
Portfolio: EVT TRM Portfolio 2018-06
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary
Reliability update: Updated and added a reference to incremental cost, as the existing measure never had a reference, just an estimate from years ago.

Referenced Documents
- 98 PIP High Perf Circ Pump_2015 Final
- 2018-res-blpm-circ-pump-analysis-hdd60

Description
This measure characterization is for installing fractional horsepower circulator pumps with brushless permanent magnet pump (BLPM) motors. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in single-family residences. Circulator pumps that use BLPMs are more efficient because they lack brushes that add friction to the motor, as well as the ability to modulate their speed to match the load. This is possible because the drive senses the difference between the magnetic field of the rotating rotor and the rotating magnetic field of the windings in the motor stator. As the system flow demand changes (zones open or close), the drive senses the torque difference at the impeller via the change in the magnetic field difference and adjusts its speed by altering the frequency to the motor. BLPMs are especially efficient in no-load/low-load applications.

The Efficiency Vermont High Performance Circulator Pump (HPCP) Program is a program to promote the installation of efficient brushless permanent magnet motor (BLPM) circulator pumps with integrated variable speed controls in Vermont homes and businesses. The program is offered to HVAC distributors who sell/ship equipment in Vermont, and provides upstream financial incentives at the wholesale level for qualifying circulator pumps sold for installation in a commercial facility or residential home in Vermont.

Baseline Efficiencies
The baseline equipment is a circulator pump using a low-efficiency shaded pole motor. It is assumed that this pump is installed on the primary loop of a multi-loop system, and is running constantly when outside temperatures are 55°F or lower during the winter heating season (October – April).

Efficient Equipment
The efficient equipment is a circulator pump with brushless permanent magnet motor.

Algorithms
Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	= HOURS x $((Watts_{Base} - Watts_{EE}) / 1000)$ x ISR

Symbol Table

Fossil Fuel Savings
Midlife Adjustment
Water Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW) = 0.06598 kW
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh) = 87.5 kWh
HOURS	=	1,325[1]
ISR	=	In Service Rate, or the percentage of units rebated that actually get used = 90%[2]
$Watts_{Base}$	=	Baseline connected kW = 87.7 Watts[3]
$Watts_{EE}$	=	Energy efficient connected kW = 14.4 Watts[3]

Load Shapes
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%

Net Savings Factors
Measures

MTRCIRCZ	BLPM Boiler Circ Motor - Res

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Lifetimes
20 years – typical circulator pumps using shaded pole motors are expected to last around 15 years; circulator pump motors with ECMs typically operate at lower RPMs, thus producing less heat and extending the life of the motor.

Measure Cost
The estimated incremental cost for this measure is $127[4].

O&M Cost Adjustments

There are no O&M cost adjustments associated with this measure.

Persistence

The persistence factor is assumed to be 1.

Footnotes

[1] Efficiency Vermont performed a metering study to better understand run hours of high performance circulator pumps. Analysis can be found in 2018 RES BLPM CIRC PUMP Analysis_HDD60.xlsx.

[2] In-Service Rate Study performed by Efficiency Vermont and Technical Advisory Group (TAG) 2015 agreement found the annual ISR to be 90%.

[3] Efficiency Vermont performed a metering study to better understand watt draw. Analysis can be found in 2018 RES BLPM CIRC PUMP Analysis_HDD60.xlsx.

[4] These values are based on an incremental cost per watt of $8.82. Analysis of baseline pump costs and high efficiency pump costs. Costs are found in Wilo's Price Book - Pumps and systems for Building Services and Groundwater. Accessed 4/29/2018. http://www.wilo-usa.com/fileadmin/us/Price_Pages/2016_WiloUSA_ListPricing_BuildingServices_0216.pdf. Analysis can be found on Incremental Costs tab of 2018-blpm-circ-pump-analysis-hdd60.xlsx.

Residential Efficient Space Heating System

Measure Number: VII-C-7 b
Portfolio: EVT TRM Portfolio 2017-07
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

This is a reliability update that includes an updated VGS Data Regression Analysis for EFLH calculations, which aligns with the Advanced Thermostat measure. Average capacity of heating systems was updated to show actual data from VGS Data Regression. As costs are directly linked to capacity and efficiencies, the costs were also updated with this reliability update.

Referenced Documents

- DOE_Small_appendix_e
- NEEP Residential Boilers 2011_08_18
- NEEP Residential Furnace Analysis 2011_08_19
- NEEP Incremental Cost Study Report 2011
- VT SF Existing Homes Onsite Report_final 021513
- vgs-usage-regression-work-06272017-xlsx
- residential-heating_and_cooling-systems-initiative_cee
- EVT_RES Efficient Space Heating Savings_Analysis_July 2017
- evt-estimated-heating-full-load-hours-July-2017
- furnaces_nopr_tsd_2015-02-13
- technical-support-document---residential-boilers_doe
- CostsFurnacesBoilersNEW

Description

This measure applies to the installation of primary oil- or propane-fired boiler or furnace heating systems in residential existing homes applications. Fossil fuel savings are realized due to the higher AFUE of the qualifying equipment. All systems must be installed per the VT Residential Building Energy Standards and all boiler installations must incorporate high performance Circulator Pumps (electric savings for this will be claimed based on existing measure characterizations).

This measure will provide a standard incentive through two channels. First through the existing Home Performance with ENERGY STAR (HPwES) program where this measure will continue to be treated as an Early Replacement since Efficiency Vermont's involvement results in replacements that would not likely have occurred otherwise. The savings from HPwES projects are generated through modeling software (not characterized here), and a mid life baseline shift will be incorporated to account for the hypothetical future baseline replacement at the AFUE level presented below, consistent with the Market Opportunity measure. The second channel is through the Energy Efficiency Network (EEN) whereby member HVAC contractors and fuel dealers will be able to offer an identical incentive for their customers to upsell to the higher efficiency levels. For measures installed this way (outside of Home Performance with ENERGY STAR) a market opportunity baseline will be used.

Baseline Efficiencies

Baseline equipment is a new standard efficiency oil- or propane-fired furnace or boiler with an AFUE provided below.

Efficient Equipment

The installed oil or propane furnace or boiler must have an AFUE greater than those shown below.

Unit Type	$AFUE_{Base}$	$AFUE_{Eff}$
Oil Boiler	85%	87%
LP Boiler	86.7%	95%
Oil Furnace	82.6%	87%
LP Furnace	88%	95%

Algorithms

Electric Demand Savings
N/A

Electric Energy Savings
The electrical energy and demand savings associated with high performance Circulator Pump is provided in a standalone characterization.

Fossil Fuel Savings

ΔMMBTU	$= (FLH \times (Capacity / 1,000,000) \times (1/AFUE_{Base} - 1 / AFUE_{Eff})$

Refer to the table of deemed savings in Measure Savings Summary section below.

Symbol Table

Midlife Adjustment
For the Early Replacement measure the initial baseline is the existing unit efficiency. A mid life baseline adjustment will be incorporated to account for the hypothetical new baseline replacement at the same AFUEbase level provided below. It is assumed that this baseline shift will occur after a third of the measure life – so after 5 years for furnaces and 8.3 years for boilers.

Where:

ΔMMBTU	=	Gross customer annual MMBtu fuel savings for the measure.
1,000,000	=	Conversion from Btuh to MMBtu/hour.
$AFUE_{Base}$	=	Efficiency of baseline equipment in AFUE[1]. Refer to table above in Efficient Equipment section.
$AFUE_{Eff}$	=	Efficiency of new equipment in AFUE[2]. Refer to table above in Efficient Equipment section.
Capacity	=	capacity of equipment to be installed (Btuh)[3]

Unit Type	Capacity (Btuh)
Boiler	97,754
Furnace	78,379

FLH	=	Estimated average full load heating hours. = 714 for boilers and 922 for furnaces[4]

Load Shapes

N/A

Net Savings Factors

Measures

SHRBFOIL	Replace boiler, fuel oil
SHRBPROP	Replace boiler, propane
SHRFFOIL	Replace furnace, fuel oil
SHRFPROP	Replace furnace, propane

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	SHRBFOIL	1.00	1.00
Res Retrofit	6036RETR	SHRBPROP	1.00	1.00
Res Retrofit	6036RETR	SHRFFOIL	1.00	1.00
Res Retrofit	6036RETR	SHRFPROP	1.00	1.00

Lifetimes

Equipment Type	Measure Lifetime[5]
Furnaces	15
Boilers	25

Measure Cost

The incremental costs of more efficient equipment are detailed below[6]:

Unit Type	Baseline cost	Efficient Cost	Incremental Cost
Oil Boiler	$4,316	$4,642	$326
LP Boiler	$4,894	$6,843	$1,948
Oil Furnace	$2,906	$3,574	$668
LP Furnace	$2,594	$3,341	$747

Costs for the early replacement measure include the baseline avoided cost in the midlife adjustment.

O&M Cost Adjustments

O&M cost estimates for baseline and efficient boilers and furnaces are provided below[7]

Unit Type	Baseline Annual O&M Cost	Efficient Annual O&M Cost
Boilers	$89.55	$92.55
Furnaces	$39.55	$40.06

Persistence

The persistence factor is assumed to be one.

Measure Savings Summary

Unit Type	ΔMMBTU
Oil Boiler	1.9
LP Boiler	7.0
Oil Furnace	4.4
LP Furnace	6.1

Footnotes

[1] Based on the average findings from p60, NMR Group Inc "Vermont Single-Family Existing Homes Onsite Report. Final 2/15/2013". Note these are significantly above the Federal Minimum Standard but represent an estimate of what people are purchasing without Efficiency Vermont intervention.

[2] The efficiency criteria were developed based on consideration of availability of product, incremental cost etc and with input from EEN representatives.

[3] Average of capacities of boilers and furnaces found in VGS Usage Regression work. See Cells AP11 and AP12 in vgs-usage-regression-work-06272017-xlsx.xlsx. Assumed average values used for prescriptive savings purposes

[4] Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. The RNC data was limited to only those homes with annual gas consumption greater than 25 kBtu/SF in an attempt to remove the high performance/ low load homes in RNC. See "EVT estimated heating full load hours.doc" for greater explanation and Cells AM11 and AM12 on EFL Filtered tab 'vgs-usage-regression-work-06272017' for analysis.

[5] Page 8, Residential Heating and Cooling Systems Initiative Description, CEE, May 28, 2015. residential-heating_and_cooling-systems-initiative_cee.pdf.

[6] Costs are derived based upon the NEEP Incremental Cost Study (http://neep.org/emv-forum/forum-products-and-guidelines/#Incremental) and also cross checking with the DOE Technical Appliance Standards Technical Support Document "Appendix E. Engineering Analysis Cost and Efficiency Tables". See 'CostsFurnacesBoilersNEW.xls'.

[7] O&M Costs originate from 2015 DOE Technical Support documents for residential furnaces and boilers: furnaces_nopr_tsd_2015-02-13.pdf and technical-support-document---residential-boilers_doe.pdf. Please find the trend anlaysis on the O&M Costs sheet of the analysis document: CostsFurnacesBoilersNEW.xlsx.

Pellet & Wood Stoves

Measure Number: VIII-C-13 a
Portfolio: EVT TRM Portfolio 2018-08
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

New measure

Referenced Documents

- VT SF Existing Homes Onsite Report_final 021513
- VGS Usage Regression Work_04182017
- NMR_Survey Analysis of Owners in Existing Homes in Vermont_Dec 2016
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- EIA_Updated Bldg Sector Appliance & Equipment Costs_June 2018
- VT Dept of Forests_Residential Fuel Assessment Report_Mar 2016
- VT Dept of Public Service_November 2016 Fuel Price Report
- EVT_Pellet Wood Stoves_Analysis_Aug 2018 _v2

Description

This is a retrofit measure that applies to the installation by an approved contractor of a new wood or pellet stove in a new or existing residential building. It is assumed that the home will use a second space heating system in addition to the stove and that the stove will offset a portion of the existing heating system's fuel consumption.

Stoves must be installed according to manufacturer's recommendations and meet the following minimum efficiency and emissions requirements:

- 70% efficiency
- ≤2.0 of particulate matter less than 2.5 microns ($PM_{2.5}$)[1]

This measure provides separate assumptions for replacement of existing wood stoves that are still operational. Existing stoves must be non-EPA certified or if EPA-certified, manufactured prior to 1998 and not meeting 2020 New Source Performance Standards.

Baseline Efficiencies

For customers who are not replacing an existing wood stove, the baseline is a blend of LP, oil, wood, pellet, and electric heating systems, based on the percentage of each system installed as a primary heating source in existing Vermont homes for retrofits or in new Vermont homes for new construction (NC).

For customers replacing an existing wood stove, the baseline is an existing wood stove that is still operational. Existing stoves must be non-EPA certified or if EPA-certified, manufactured prior to 1998 and not meeting 2020 New Source Performance Standards.

Efficient Equipment

The new equipment must be a new wood or pellet stove installed according to manufacturer's recommendations and meeting minimum efficiency and emissions requirements.

In 2018 and forward, in TEPF-funded programs, EVT will not count the increased wood fuel use associated with biomass fuel switches from fossil fuels. Therefore, this measure does not apply a biomass heating penalty, except when the baseline is wood or pellets.

Algorithms

Electric Demand Savings

New pellet or wood stove, not replacing existing wood stove: ΔkW	$= \Delta kWh_{Net} / FLH_{Central}$
Replacing existing wood stove with new pellet stove: ΔkW	$= \Delta kWh_{Net} / FLH_{Stove}$

Symbol Table

Electric Energy Savings

The electric and demand savings from the use of a new pellet or wood stove in place of an existing electric central heating system and the electric and demand penalties from the use of a new pellet stove are described below.

For customers that are not replacing existing wood stoves:

Measure Code	Item Code	Building Type	New Stove Type	ΔkWh_{Save}	$\Delta kWh_{Penalty}$	ΔkWh_{Net}	ΔkW
SHFHWOOD	RES-STOVE-W-EH1	Existing	Wood	190.5	N/A	190.5	0.24423
SHFHWODP	RES-STOVE-P-EH1		Pellet	187.5	-175.0	12.5	0.01603
SHFHWOOD	RES-STOVE-W-NC1	NC	Wood	486.6	N/A	486.6	0.74290
SHFHWODP	RES-STOVE-P-NC1		Pellet	479.1	-175.0	304.1	0.46427

For customers that are replacing existing wood stoves:

Measure Code	Item Code	Building Type	New Stove Type	ΔkWh_{Save}	$\Delta kWh_{Penalty}$	ΔkWh_{Net}	ΔkW
SHRHWOOD	RES-STOVE-W-ER2	Existing	Wood	N/A	0.0	0.0	0.00000
SHRHWODP	RES-STOVE-P-ER2		Pellet	N/A	-175.0	-175.0	-0.12500

New pellet stove, not replacing existing wood stove: ΔkWh_{Net}	$= \Delta kWh_{Save} - \Delta kWh_{Penalty}$
New wood stove, not replacing existing wood stove: ΔkWh_{Net}	$= \Delta kWh_{Save}$
Replacing existing wood stove with new stove: ΔkWh_{Net}	$= \Delta kWh_{Penalty}$
ΔkWh_{Save}	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Base, Electric} \times 293.071 \times \%stove \times \%Elec$
$\Delta kWh_{Penalty}$	$= FLH_{Stove} \times (Watts_{Stove} / 1{,}000)$

Symbol Table

Fossil Fuel Savings

The fuel savings from the use of a new pellet or wood stove in place of an LP, oil, wood, or pellet heating system or an existing wood stove, the fuel penalties from the use of a new pellet or wood stove, and net savings for each baseline fuel type are described below.

For customers that are not replacing existing wood stoves:

Measure Code	Item Code	Building Type	New Stove Type	Baseline System Fuel Type	$\Delta MMBtu_{Save}$ (by fuel type)	$\Delta MMBtu_{Penalty}$	$\Delta MMBtu_{Net}$ (total savings after applying penalty)
SHFHWOOD	RES-STOVE-W-EH1		Wood	LP	10.659	N/A	10.695
				Oil	40.192	N/A	40.192
				Wood	4.071	3.528	0.543
				Pellet	0.000	N/A	0.000

		Existing					
SHFHWODP	RES-STOVE-P-EH1		Pellet	LP	10.495	N/A	10.495
				Oil	39.574	N/A	39.574
				Wood	4.008	N/A	4.008
				Pellet	0.000	3.428	-3.428
SHFHWOOD	RES-STOVE-W-NC1	NC	Wood	LP	21.264	N/A	21.264
				Oil	2.357	N/A	2.357
				Wood	11.595	15.690	-4.095
				Pellet	4.042	N/A	4.042
SHFHWODP	RES-STOVE-P-NC1		Pellet	LP	20.937	N/A	20.937
				Oil	2.321	N/A	2.321
				Wood	11.416	N/A	11.416
				Pellet	3.979	15.246	-11.267

For customers that are not replacing existing wood stoves with new pellet or wood stoves, MMBtu savings and penalties are provided below. A mid-life adjustment should be applied after 10 years, which is assumed to be the remaining life of the existing wood stove. At that point, it is assumed that the customer would install a new, baseline stove.

Measure Code	Item Code	Building Type	New Stove Fuel Type	$\Delta MMBtu_{Save}$ for the remaining life of the existing stove (first 10 years)	$\Delta MMBtu_{Save}$ for the remaining measure life (next 8 years)	$\Delta MMBtu_{Penalty}$	$\Delta MMBtu_{Net}$ for the remaining life of the existing stove (first 10 years)	$\Delta MMBtu_{Net}$ for the remaining measure life (next 8 years)	Mid-Life Adjustment (applied after first 10 years)
SHRHWOOD	RES-STOVE-W-ER2	Existing	Wood	89.273	63.592	61.896	27.377	1.696	6.2%
SHRHWODP	RES-STOVE-P-ER2		Pellet			60.142	29.131	3.450	11.8%

$\Delta MMBtu_{Net}$	$= \Delta MMBtu_{Save} - \Delta MMBtu_{Penalty}$
LP savings, not replacing existing wood stove: $\Delta MMBtu_{Save, LP}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Base, LP} \times \%stove \times \%Fuel_{LP}$
Oil savings, not replacing existing wood stove: $\Delta MMBtu_{Save, Oil}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Base, Oil} \times \%stove \times \%Fuel_{Oil}$
Wood savings, not replacing existing wood stove: $\Delta MMBtu_{Save, Wood}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Base, Wood} \times \%stove \times \%Fuel_{Wood}$
Pellet savings, not replacing existing wood stove: $\Delta MMBtu_{Save, Pellet}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Base, Pellet} \times \%stove \times \%Fuel_{Pellet}$
Penalty, not replacing existing wood stove: $\Delta MMBtu_{Penalty}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{New\ Stove} \times \%stove \times (\%Fuel_{Wood} + \%Fuel_{Pellet})$
Savings, replacing existing wood stove (first 10 years): $\Delta MMBtu_{Save}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Existing\ Stove} \times \%stove$
Savings, replacing existing wood stove (next 8 years): $\Delta MMBtu_{Save}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{Baseline\ Stove} \times \%stove$
Penalty, replacing existing wood stove: $\Delta MMBtu_{Penalty}$	$= FLH_{Central} \times (Capacity / 1{,}000{,}000) / n_{New\ Stove} \times \%stove$

Where:

%Elec = Percentage of homes assumed to have electric heating systems; see table below

Building Type	%Elec
Existing[4]	1.4%
New Construction[5]	15.4%

$\%Fuel_{LP}$ = Percentage of homes assumed to use LP heating systems; see table within $\%Fuel_{Wood}$ definition for for each building type and fuel type.

$\%Fuel_{Oil}$ = Percentage of homes assumed to use oil heating systems; see table within $\%Fuel_{Wood}$ definition.

$\%Fuel_{Pellet}$ = Percentage of homes assumed to use pellet heating systems; see table within $\%Fuel_{Wood}$ definition.

$\%Fuel_{Wood}$ = Percentage of homes assumed to use wood heating systems; see table below for %Fuel for each building type and fuel type.

Building Type	Fuel Type	%Fuel
Existing[4]	LP	20.0%
	Oil	72.9%
	Wood	5.7%
	Pellet	0.0%
New Construction[5]	LP	50.0%
	Oil	5.1%
	Wood	21.8%
	Pellet	7.7%

%stove = Percentage of annual total heating load provided by stove

%stove	
Wood[6]	Pellet[7]
65%	64%

ΔkW = Gross customer annual connected load kW savings for the measure

ΔkWh_{Net} = Gross customer annual kWh savings for the measure after subtracting the kWh penalty from use of a pellet stove

$\Delta kWh_{Penalty}$ = Gross annual kWh penalty from the use of a pellet stove

ΔkWh_{Save} = Gross customer annual kWh savings for the measure

$\Delta MMBtu_{Net}$ = Gross customer annual MMBtu fuel savings for the measure after subtracting the MMBtu penalty

$\Delta MMBtu_{Penalty}$ = Gross customer annual MMBtu fuel penalty from use of cordwood or pellets, based on the percentage of wood and pellet space heating in homes

$\Delta MMBtu_{Save, LP}$ = Gross customer annual MMBtu fuel savings for the measure (LP baseline)

$\Delta MMBtu_{Save, Oil}$ = Gross customer annual MMBtu fuel savings for the measure (oil baseline)

$\Delta MMBtu_{Save, Pellet}$ = Gross customer annual MMBtu fuel savings for the measure (pellet baseline)

$\Delta MMBtu_{Save, Wood}$ = Gross customer annual MMBtu fuel savings for the measure (wood baseline)

$\Delta MMBtu_{Save}$ = Gross customer annual MMBtu fuel savings for the measure (calculated separately for each baseline fuel type)

1,000,000 = Factor to convert Btu/hr to MMBtu/hr

293.071 = Factor to convert MMBtu to kWh

Capacity = Average capacity of primary space heating systems installed in Vermont homes

Building Type	Capacity[2]
Existing	91,562
NC	93,695

$FLH_{Central}$ = Average full load heating hours of central space heating systems in Vermont homes

Building Type	FLH[2]
Existing	780
NC	655

FLH_{Stove} = Average full load heating hours of stoves

= 1,400[3]

$\eta_{Base, Pellet}$ = Efficiency of baseline pellet heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, Electric}$ = Efficiency of baseline electric heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, LP}$ = Efficiency of baseline LP heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, Oil}$ = Efficiency of baseline oil heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, Wood}$ = Efficiency of baseline wood heating system; see table below for ηBase values based on building type and fuel type

Building Type	Fuel Type	η_{Base}
Existing[9]	Electric	1.00
	LP	0.871
	Oil	0.842
	Wood	0.65
New Construction[10]	Electric	3.7
	LP	0.938
	Oil	0.863
	Wood	0.75
	Pellet	0.76

$\eta_{Baseline Stove}$ = Efficiency of baseline stove that it is assumed a customer would install after the remaining life of the existing wood stove (10 years)

= 0.73[11]

$\eta_{Existing Stove}$ = Efficiency of existing wood stove that is being replaced

= 0.52[12]

$\eta_{New Stove}$ = Efficiency of new stove[13]

New Stove Type	$\eta_{New Stove}$
Wood	0.75
Pellet	0.76

$Watts_{Stove}$ = Energy consumption (watts) of new stove

New Stove Type	$Watts_{Stove}$
Wood	0
Pellet	125[8]

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%

Net Savings Factors

Measures

SHFHWOOD	Fuel switch, space heater, wood
SHRHWOOD	Replace space heater, wood
SHFHWODP	Fuel switch, space heater, wood pellet
SHRHWODP	Replace space heater, wood pellet

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6032UPST [6032EPEP]	Upstream - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LISF Retrofit	6034LISF	SHFHWOOD	1.00	1.00
LISF Retrofit	6034LISF	SHRHWOOD	1.00	1.00
LISF Retrofit	6034LISF	SHFHWODP	1.00	1.00
LISF Retrofit	6034LISF	SHRHWODP	1.00	1.00

Lifetimes

The expected measure life is assumed to be 18 years.[14]

For early replacement of wood stoves, the existing wood stove is assumed to have a remaining life of 10 years.

Measure Cost

The measure cost is the total installed cost (equipment and labor) for a wood or pellet stove:[15]

New Stove Type	Stove Cost	Installation Cost	Other Costs*	Total Installed Cost
Cordwood	$2,475	$383	$469	$3,319

Pellet	$3,366	$340	$694	$4,400

*Costs not included in "stove cost" or "installation cost," such as miscellaneous parts or recycling fees.

For early replacement of wood stoves, the assumed deferred cost (after 10 years) of replacing existing equipment with a new baseline wood stove meeting New Source Performance Standards is assumed to be $2,655.[16]

O&M Cost Adjustments

For customers that are not replacing existing wood stoves:

Building Type	New Stove Type	Annual Baseline O&M Cost[17]	Annual O&M Costs with New Stove[18]	Annual O&M Cost Adjustment (Penalty)
Existing	Wood	$106	$229	-$123
	Pellet		$298	-$192
NC	Wood	$125	$236	-$111
	Pellet		$305	-$180

For customers that are replacing existing wood stoves with new pellet or wood stoves:

Annual Baseline O&M Cost[19]	New Stove Type	Annual O&M Costs with New Stove[19]	Annual O&M Cost Adjustment (Penalty)
$192	Wood	$192	$0
	Pellet	$260	-$68

Footnotes

[1] Requirement from EPA New Source Performance Standards for year 2020

[2] FLH and capacity values estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis. For existing homes, final FLH and capacity values were calculated using boiler and furnace weightings from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. For new construction, weightings are from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 47, Table 47.

[3] FLH for stoves estimated by the Biomass Energy Resource Center

[4] Percentage of heating system fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Efficiency Vermont data). Natural gas, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump." Percentage of wood from boilers and furnaces (versus stoves) estimated as 4% based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Percentage of heating system fuel types in new residential buildings in Vermont based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017: page 45, Table 46 (Efficiency Vermont data). Natural gas excluded.

[6] %stove for wood stoves is calculating using: the percentage of primary (53%) versus supplemental (47%) cordwood users in Vermont and the annual number of cords burned by primary (4.8) versus supplemental (2.1) cordwood users from Vermont Department of Forests, Parks, and Recreation, "Vermont Residential Fuel Assessment for the 2014-2015 Heating Season," March 2016, page 6; an average annual heat load of 80.832 MMBtu for Vermont homes (700 gallons/oil per year based on 2016 VT Tier III TAG agreement/84.2% oil heating system efficiency in existing VT homes); 68% stove efficiency based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment; and 22.0 MMBtu/cord heat content from the November 2016 VT Fuel Price Report. %stove is calculated as ((53% (4.8 cords/yr * 22.0 MMBtu/cord * 68% / 80.832)) + (47% (2.1 cords/yr * 22.0 MMBtu/cord * 68% / 80.832)). See %stove tab in file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculation.

[7] %stove for pellet stoves is calculating using: the percentage of primary (70%) versus supplemental (30%) pellet users in Vermont and the annual tons of pelelts burned by primary (4.4) versus supplemental (3.3) pellet users from Vermont Department of Forests, Parks, and Recreation, "Vermont Residential Fuel Assessment for the 2014-2015 Heating Season," March 2016, pages 7-8; an average annual heat load of 80.832 MMBtu for Vermont homes (700 gallons/oil per year based on 2016 VT Tier III TAG agreement/84.2% oil heating system efficiency in existing VT homes); 77% stove efficiency based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment; and 16.4 MMBtu/ton heat content from the November 2016 VT Fuel Price Report. %stove is calculated as ((70% (4.4 tons/yr * 16.4 MMBtu/ton * 77% / 80.832)) + (30% (3.3 tons/yr * 16.4 MMBtu/ton * 77% / 80.832)). See %stove tab in file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculation.

[8] Typical pellet stove energy consumption at normal burn rates estimated by the Biomass Energy Resource Center. Includes ignitor, feed auger, and blowers.

[9] Efficiencies of LP and oil heating systems in existing homes are a weighted average based on the percentage of boilers and furnaces used as single major heating system in existing Vermont homes from NMR Group, "Vermont Single-Family Existing Homes Onsite Report," February 15, 2013: pages 58-61, Tables 5-4, 5-8 and 5-9. Stoves in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of wood heating systems is based on professional judgment. See nBase & nExisting tab within file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculations.

[10] Efficiencies of electric, LP, and oil heating systems in new homes are based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Boiler, furnace, and heat pump weightings are from page 47, Table 47, and equipment efficiencies are from pages 49-50, Tables 50-52. Oil boilers, combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps were removed from boiler and furnace weighting calculations. Values for Efficiency Vermont used. nBase (LP) is a weighted average based on the percentage of LP boilers and furnaces installed in new Vermont homes. Nbase (oil) is the efficiency of oil boilers. Efficiencies of wood and pellet heating systems are the efficiencies of new stoves meeting 2020 NSPS and 70% efficiency requirements on EPA's list of certified wood heaters as of May 2018. See nBase & nExisting tab within file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculations.

[11] Efficiency of baseline stove is the average efficiency of stoves meeting 2020 NSPS requirements from EPA's list of certified stoves as of May 2018.

[12] Efficiency of existing wood stove being replaced is an estimate provided by the Biomass Energy Resource Center based on review of information provided by the Alliance for Green Heat.

[13] Average efficiency of new stoves meeting 2020 NSPS and 70% efficiency requirements on EPA list of certified wood heaters as of May 2018

[14] Average of lifetimes provided for residential cordwood and pellet stoves in U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," June 2018.

[15] Average costs from the Renewable Energy Resource Center from December 2016 through April 2017. See Measure Cost tab within file EVT_Pellet Wood Stove Analysis_Aug 2018_v2.xlsx.

[16] Based on estimate that a baseline stove meeting NSPS standards costs 80% of an average stove meeting program requirements.

[17] Baseline O&M costs for existing homes are based on the percentage of each heating system fuel type in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Efficiency Vermont data). LP and oil systems are weighted based on the percentage of boilers and furnaces in Vermont homes from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. Baseline O&M costs for new construction are based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and systems excluded. Costs for LP and oil boilers and furnaces, wood stoves, pellet stoves, and heat pumps are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. Costs for cordwood boilers and furnaces are assumed to the same as costs for pellet boilers. See "O&M Costs" tab in file EVT_Pellet & Wood Stoves_Analysis_Aug 2018_v2.xlsx for calculation.

[18] O&M costs with new wood stove include the percentage of existing heat system O&M costs that are not displaced by the new stove (Baseline O&M Cost * (1 - %stove)), plus the full O&M costs associated with the new stove. New stove O&M costs are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. See O&M Costs tab within file EVT_Pellet Wood Stoves_Analysis_Aug 2018_v2.xlsx for calculation.

[19] Baseline and new O&M costs for customers replacing existing wood stoves are the full O&M costs for wood or pellet stoves from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016.

Conveyor Oven

Measure Number: CI-CKE-CONOV a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

New Measure

Referenced Documents

- PGECOFST117 R5 Commercial Conveyor Oven-Gas
- FSTC_ConveyorOven

Description

This measure applies to natural gas fired Conveyor Ovens installed in a commercial kitchen. Conveyor ovens are typically used for producing a limited number of products with similar cooking requirements at high production rates, such as pizzas, breads and pastries.

Some manufacturers offer an air-curtain feature at either end of the cooking chamber that helps to keep the heated air inside the conveyor oven. The air curtain operates as a virtual oven wall and helps reduce both the idle energy of the oven and the resultant heat gain to the kitchen.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Mid stream

Baseline Efficiencies

The baseline equipment is a new standard gas-fired conveyor oven.

Efficient Equipment

The efficient equipment is a gas fired conveyor oven with baking efficiency of at least 42% and idle energy rate less than or equal to 57,000 Btuh/h, utilizing ASTM Standard F1817.

Algorithms

Electric Demand Savings
Electric Energy Savings

Fossil Fuel Savings
All assumptions except where noted are based on Work Paper PGECOFST117 Commercial Conveyor Oven-Gas .

Using assumptions provided, the deemed savings for this measure is 75.6 MMBtu (Item Code CKE-CONVY-NG or CKE-CONVY-LP depending on fuel type)

ΔMMBtu	= (ΔPreheatDailyBtu + ΔIdleDailyBtu +ΔCookingDailyBtu) × Days/1000000
ΔIdleDailyBtu	= ($IdleRateGas_{Base}$ × (Hours - FoodCooked/$ProductionGas_{Base}$ - (Preheats × PreheatTime/60)) - ($IdleRateGas_{EE}$ × (Hours - FoodCooked/$ProductionGas_{EE}$ - (Preheats × PreheatTime/60))
ΔCookingDailyBtu	= (FoodCooked × $EFOOD_{Gas}$/EFF_{Base}) - (FoodCooked × $EFOOD_{Gas}$/EFF_{EE})
ΔPreheatDailyBtu	= ($PreheatEnergy_{Base}$ × Preheats) - ($PreheatEnergy_{EE}$ × Preheats)

Where:

ΔCookingDailyBtu	=	Energy savings per day to cook food in gas conveyor oven (Btu)
ΔIdleDailyBtu	=	Energy savings per day when gas conveyor oven is idle (Btu)
ΔMMBtu	=	Total gas savings for gas conveyor oven (MMBtu)
ΔPreheatDailyBtu	=	Energy savings per day when gas conveyor oven is preheating (Btu)
60	=	Converts minutes to hours
Days	=	Annual days of kitchen operation = 312[1]
EFF_{Base}	=	Cooking efficiency of baseline conveyor oven = 20%
EFF_{EE}	=	Cooking efficiency of efficient conveyor oven = 42%
$EFOOD_{Gas}$	=	ASTM energy to food for gas conveyor oven = 190 Btu/pizza
FoodCooked	=	Food cooked per day = 250 pizzas
Hours	=	Average daily hours of operation = 12 hours
$IdleRateGas_{Base}$	=	Idle energy rate of baseline gas conveyor oven = 70,000 Btu/hr
$IdleRateGas_{EE}$	=	Idle energy rate of efficient gas conveyor oven = 57,000 Btu/hr
$PreheatEnergy_{Base}$	=	Preheat energy of baseline gas conveyor oven = 35,000 Btu
$PreheatEnergy_{EE}$	=	Preheat energy of efficient gas conveyor oven = 18,000 Btu
Preheats	=	Number of preheats per day

		= 1
PreheatTime	=	Length of one preheat = 15 minutes
$ProductionGas_{Base}$	=	Production capacity of baseline gas conveyor oven = 150 pizzas per hour
$ProductionGas_{EE}$	=	Production capacity of efficient gas conveyor oven = 220 pizzas per hour

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLCONVE	Gas Conveyor Oven

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLCONVE	1.00	1.00

Lifetimes

Lifetime is assumed as 12 years[2]

Measure Cost

Incremental costs are assumed to be $2,230 per oven [3]

Footnotes

[1] Reduced from 365 days assumed in the PS&E Workpaper to account for Vermont seasonal operation and kitchens not operating every day. Assumes an average of 6 days per week operation.

[2] Based on Pacific Gas & Electric Company Work Paper PGECOFST117 "Commercial Conveyor Oven - Gas", May 2014.

[3] Based on Pacific Gas & Electric Company Work Paper PGECOFST117 "Commercial Conveyor Oven - Gas", May 2014.

ENERGY STAR Commercial Dishwasher

Measure Number: CI-CKE-DISHW a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

New measure

Referenced Documents

- ENERGY STAR Dishwasher

Description

This measure describes savings from an ENERGY STAR dishwasher installed in a commercial kitchen. As per the ENERGY STAR specification, savings are provided for high and low temperature under counter, stationary single tank door, single tank conveyor and multiple tank conveyor dishwashers, as well as high temperature pot, pan and utensil dishwasher types.

Savings are also dependent on the building's water and/or booster tank heating fuel.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Mid stream

Baseline Efficiencies

Baseline is assumed to be a new dishwasher of equivalent type that is non ENERGY STAR qualified.

Efficient Equipment

The ENERGY STAR requirements as of February 1 2013 are provided below:

Dishwasher Type	High Temp Efficiency Requirements		Low Temp Efficiency Requirements	
	Idle Energy Rate	Water Consumption	Idle Energy Rate	Water Consumption
Under Counter	≤ 0.50 kW	≤ 0.86 GPR	≤ 0.50 kW	≤ 1.19 GPR
Stationary Single Tank Door	≤ 0.70 kW	≤ 0.89 GPR	≤ 0.60 kW	≤ 1.18 GPR
Pot, Pan, and Utensil	≤ 1.20 kW	≤ 0.58 GPSF	≤ 1.00 kW	≤ 0.58 GPSF
Single Tank Conveyor	≤ 1.50 kW	≤ 0.70 GPR	≤ 1.50 kW	≤ 0.79 GPR
Multiple Tank Conveyor	≤ 2.25 kW	≤ 0.54 GPR	≤ 2.00 kW	≤ 0.54 GPR

GPR: Gallons per rack

GPSF: Gallons per square foot of rack

Algorithms

Electric Demand Savings

All assumptions are taken from the ENERGY STAR Commercial Kitchen Equipment Calculator except where otherwise noted.

ΔkW	= ΔkWh / (Hours × Days)

Symbol Table

Water Savings

ΔWater	= ((WaterUseBase - WaterUseEff) × (RacksWashed × Days)) / 748

Symbol Table

Electric Energy Savings

ΔkWh	= ΔBuildingEnergyElectric + ΔBoosterEnergyElectric + ΔIdleEnergy
ΔBuildingEnergyElectric	= (ΔWater × 748 × ΔTinWaterHeater × 1.0 × 8.2)/(ElectricWaterHeaterEff × 3,412)
ΔBoosterEnergyElectric	= (ΔWater × 748 × ΔTinBoosterHeater × 1.0 × 8.2)/(ElectricBoosterHeaterEff × 3,412)
ΔIdleEnergy	= (IdleDrawBase - IdleDrawESTAR) × ((Hours × Days) - (Days × RacksWashed × WashTime/60))

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= ΔBuildingEnergyFuel + ΔBoosterEnergyFuel
ΔBuildingEnergyFuel	= (ΔWater × 748 × ΔTinWaterHeater × 1.0 × 8.2)/(FuelWaterEff × 1,000,000)
ΔBoosterEnergyFuel	= (ΔWater × 748 × ΔTinBoosterHeater × 1.0 × 8.2)/((FuelBoosterHeaterEff) × 1,000,000)

Where:

ΔBoosterEnergyElectric	=	Gross electric savings from electric booster heater (high temperature dishwashers only)
ΔBoosterEnergyFuel	=	Gross fuel savings from fuel booster heater (high temperature dishwashers only)
ΔBuildingEnergyElectric	=	Gross electric savings from electric building water heater
ΔBuildingEnergyFuel	=	Gross fuel savings from fuel building water heater
ΔIdleEnergy	=	Gross electric savings when dishwasher is idle
ΔkW	=	Gross demand savings for this measure
ΔkWh	=	Gross electric savings for this measure
ΔMMBtu	=	Gross fuel savings for this measure
ΔTinBoosterHeater	=	= Inlet water temperature increase (F) = 40 F for booster water heaters
ΔTinWaterHeater	=	= Inlet water temperature increase (F) = 70 F for building water heaters

ΔWater	=	Total water savings for this measure (ccf)
1,000,000	=	Converts Btu to MMBtu
1.0	=	Specific heat of water (Btu/lb/F)
3,412	=	Converts Btu to kWh. 1 kWh = 3412 Btu
60	=	Converts minutes to hours
748	=	Convertion from gallons to CCF. 748 gallons = 1 CCF
8.2	=	Density of water (lb/gal)
Days	=	Days of dishwasher operation = 312[1]
ElectricBoosterHeaterEff	=	Efficiency of Electric Booster Heater = 98%
ElectricWaterHeaterEff	=	Efficiency of Electric building water heater = 98%
FuelBoosterHeaterEff	=	Efficiency of Fuel booster water heater = 80%
FuelWaterEff	=	Efficiency of Fuel building water heater = 80%
Hours	=	Hours of operation per day = 18 hours
IdleDrawBase	=	Idle power draw (kW) of baseline dishwasher = See table below for defaults
IdleDrawESTAR	=	Idle power draw (kW) of ENERGY STAR dishwasher = See table below for defaults
RacksWashed	=	Number of racks washed per day = See table below for defaults
WashTime	=	Time per wash cycle = See table below for defaults
WaterUseBase	=	Water use per rack (gallons) of baseline dishwasher = See table below for defaults
WaterUseEff	=	Water use per rack (gallons) of ENERGY STAR dishwasher = See table below for defaults

	RacksWashed	WashTime	WaterUse		IdleDraw	
	All Dishwashers	All Dishwashers	Base	ENERGY STAR	Base	ENERGY STAR
Low Temperature						
Under Counter	75	2	1.73	1.19	0.5	0.5
Stationary Single Tank Door	280	1.5	2.1	1.18	0.6	0.6
Single Tank Conveyor	400	0.3	1.31	0.79	1.6	1.5
Multi Tank Conveyor	600	0.3	1.04	0.54	2	2
High Temperature						
Under Counter	75	2	1.09	0.86	0.76	0.5
Stationary Single Tank Door	280	1	1.29	0.89	0.87	0.7
Single Tank Conveyor	400	0.3	0.87	0.7	1.93	1.5
Multi Tank Conveyor	600	0.2	0.97	0.54	2.59	2.25
Pot, Pan, and Utensil	280	3	0.7	0.58	1.2	1.2

Default savings are provided below, based on building water heat for low temp units and building and booster water heat for high temp units:

		Electric Building Water Heater					Fuel Building Water Heater				
	Dishwasher type	ΔkWh	ΔkW	ΔMMBtu	ΔWater	ItemCode	ΔkWh	ΔkW	ΔMMBtu	ΔWater	ItemCode
Low Temp	Under Counter	2,171	0.3865	0	17	CKE-DISH-E-L1	0	0.0000	9	17	CKE-DISH-NG-L1 CKE-DISH-LP-L1 CKE-DISH-OL-L1
	Stationary Single Tank Door	13,807	2.4585	0	107	CKE-DISH-E-L2	0	0.0000	58	107	CKE-DISH-NG-L2 CKE-DISH-LP-L2 CKE-DISH-OL-L2
	Single Tank Conveyor	11,648	2.0740	0	87	CKE-DISH-E-L3	499	0.0889	47	87	CKE-DISH-NG-L3 CKE-DISH-LP-L3 CKE-DISH-OL-3
	Multi Tank Conveyor	16,080	2.8632	0	125	CKE-DISH-E-L4	0	0.0000	67	125	CKE-DISH-NG-L4 CKE-DISH-LP-L4 CKE-DISH-OL-L4

		Electric Building Water Heater, Electric Booster					Electric Building water Heater, Fuel Booster					Fuel Building Water Heater, Electric Booster					Fuel Building Water Heater, Fuel Booster				
	Dishwasher type	ΔkWh	ΔkW	ΔMMBtu	ΔWater	ItemCode	ΔkWh	ΔkW	ΔMMBtu	ΔWater	ItemCode	ΔkWh	ΔkW	ΔMMBtu	ΔWater	ItemCode	ΔkWh	ΔkW	ΔMMBtu	ΔWater	ItemCode
	Under Counter	2,710	0.4826	0	7	CKE-DISH-EE-H1	2,182	0.3885	2	7	CKE-DISH-ENG-H1 CKE-DISH-ELP-H1	1,786	0.3180	4	7	CKE-DISH-NGE-H1 CKE-DISH-LPE-H1 CKE-DISH-OLE-H1	1,257	0.2239	6	7	CKE-DISH-NGNG-H1 CKE-DISH-LPLP-H1 CKE-DISH-OLNG-H1 CKE-DISH-OLLP-H1
	Stationary Single Tank Door	10,141	1.8057	0	47	CKE-DISH-EE-H2	6,710	1.1949	14	47	CKE-DISH-ENG-H2 CKE-DISH-ELP-H2	4,138	0.7367	25	47	CKE-DISH-NGE-H2 CKE-DISH-LPE-H2 CKE-DISH-	707	0.1259	39	47	CKE-DISH-NGNG-H2 CKE-DISH-LPLP-H2 CKE-DISH-OLNG-H2

																OLE-H2					CKE- DISH- OLLP-H2
High Temp	Single Tank Conveyor	7,874	1.4021	0	28	CKE-DISH-EE-H3	5,791	1.0312	9	28	CKE-DISH-ENG-H3 CKE-DISH-ELP-H3	4,229	0.7531	15	28	CKE-DISH-NGE-H3 CKE-DISH-LPE-H3 CKE-DISH-OLE-H3	2,147	0.3822	24	28	CKE-DISH-NGNG-H3 CKE-DISH-LPLP-H3 CKE-DISH-OLNG-H3 CKE-DISH-OLLP-H3
	Multi Tank Conveyor	23,428	4.1716	0	108	CKE-DISH-EE-H4	15,526	2.7646	33	108	CKE-DISH-ENG-H4 CKE-DISH-ELP-H4	9,599	1.7093	58	108	CKE-DISH-NGE-H4 CKE-DISH-LPE-H4 CKE-DISH-OLE-H4	1,697	0.3022	91	108	CKE-DISH-NGNG-H4 CKE-DISH-LPLP-H4 CKE-DISH-OLNG-H4 CKE-DISH-OLLP-H4
	Pot, Pan, and Utensil	2,830	0.5039	0	14	CKE-DISH-EE-H5	1,801	0.3207	4	14	CKE-DISH-ENG-H5 CKE-DISH-ELP-H5	1,029	0.1832	8	14	CKE-DISH-NGE-H5 CKE-DISH-LPE-H5 CKE-DISH-OLE-H5	0	0.0000	12	14	CKE-DISH-NGNG-H5 CKE-DISH-LPLP-H5 CKE-DISH-OLNG-H5 CKE-DISH-OLLP-H5

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLCDISH	ENERGY STAR Commercial Dishwasher

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLCDISH	1.00	1.00

Lifetimes

The assumed measure life is provided below[2]:

Dishwasher Type		Equipment Life
Low Temp	Under Counter	10
	Stationary Single Tank Door	15
	Single Tank Conveyor	20
	Multi Tank Conveyor	20
High Temp	Under Counter	10
	Stationary Single Tank Door	15
	Single Tank Conveyor	20
	Multi Tank Conveyor	20
	Pot, Pan, and Utensil	10

Measure Cost

Assumed incremental costs are provided below[3]:

Dishwasher Type		Incremental Cost
Low Temp	Under Counter	$234
	Stationary Single Tank Door	$662
	Single Tank Conveyor	$0
	Multi Tank Conveyor	$970
High Temp	Under Counter	$2025
	Stationary Single Tank Door	$995
	Single Tank Conveyor	$2050
	Multi Tank Conveyor	$970
	Pot, Pan, and Utensil	$1710

Footnotes

[1] Reduced from 365 days assumed in the ENERGY STAR calculator to account for seasonal operation and kitchens not operating every day. Assumes an average of 6 days per week operation.

[2] Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as "EPA/FSTC research on available models, 2013"

[3] Based on assumption provided in the ENERGY STAR Commercial Kitchen Equipment Savings Calculator.

ENERGY STAR Fryer

Measure Number: CI-CKE-FRYER a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

New Measure

Referenced Documents

- ENERGY STAR Fryer_2020

Description

This measure applies to electric or natural gas fired ENERGY STAR certified fryers installed in a commercial kitchen. ENERGY STAR fryers offer shorter cook times and higher production rates through advanced burner and heat exchanger designs, and fry pot insulation reduces standby losses, resulting in lower idle energy rates.

Standard-sized ENERGY STAR fryers are up to 30% more efficient, and large-vat ENERGY STAR fryers are up to 35% more efficient, than standard fryers.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Mid stream

Baseline Efficiencies

The baseline equipment is a new electric or gas fryer that is non ENERGY-STAR certified.

Efficient Equipment

The efficient equipment is a ENERGY STAR certified fryer meeting the idle energy and cooking efficiency specifications in ENERGY STAR Version 3.0 (effective October 1, 2016), provided below:

Fryer Capacity	Electric Efficiency Requirements		Natural Gas Efficiency Requirements	
	Idle Energy Rate	Cooking Efficiency	Idle Energy Rate	Cooking Efficiency
Standard Open Deep-Fat Fryer	≤ 800 W	≥ 83%	≤ 9,000 Btu/hr	≥ 50%
Large Vat Open Deep-Fat Fryer	≤ 1,100 W	≥ 80%	≤ 12,000 Btu/hr	

Algorithms

Electric Demand Savings

All assumptions are taken from the ENERGY STAR Commercial Kitchen Equipment Calculator except where otherwise noted.

$\Delta kW = \Delta kWh/(Hours \times Days)$

Symbol Table

Electric Energy Savings

$\Delta kWh = (\Delta IdleDailykWh + \Delta CookingDailykWh) \times Days/1000$

$\Delta IdleDailykWh = (IdleRateElectric_{Base} \times (Hours - FoodCooked/ProductionElectric_{Base}) - (IdleRateElectric_{ESTAR} \times (Hours - FoodCooked/ProductionElectric_{ESTAR})$

$\Delta CookingDailykWh = (FoodCooked \times EFOOD_{Electric}/ElectricEFF_{Base}) - (FoodCooked \times EFOOD_{Electric}/ElectricEFF_{ESTAR})$

Using assumptions provided, the deemed savings for this measure is as follows;

Fryer Type	ΔkWh	ΔkW	ΔMMBtu	Itemcode
Electric Standard	2,672	0.5353	0	CKE-FRYER-ES
Electric Large Vat	2,168	0.5790	0	CKE-FRYER-ELV
Gas Standard	0	0	43.4	CKE-FRYER-NGS CKE-FRYER-LPS
Gas Large Vat	0	0	35.5	CKE-FRYER-NGLV CKE-FRYER-LPLV

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu = (\Delta IdleDailyBtu + \Delta CookingDailyBtu) \times Days/1000000$

$\Delta IdleDailyBtu = (IdleRateGas_{Base} \times (Hours - FoodCooked/ProductionGas_{Base}) - (IdleRateGas_{ESTAR} \times (Hours - FoodCooked/ProductionGas_{ESTAR})$

$\Delta CookingDailyBtu = (FoodCooked \times EFOOD_{Gas}/GasEFF_{Base}) - (FoodCooked \times EFOOD_{Gas}/GasEFF_{ESTAR})$

Where:

ΔCookingDailyBtu	=	Energy savings per day to cook food in gas fryer (Btu)
ΔCookingDailykWh	=	Energy savings per day to cook food in electric fryer (kWh)
ΔIdleDailyBtu	=	Energy savings per day when gas fryer is idle (Btu)
ΔIdleDailykWh	=	Energy savings per day when electric fryer is idle (kWh)
ΔkW	=	Total demand savings for electric fryers (kWh)
ΔkWh	=	Total electric savings for electric fryers (kWh)
ΔMMBtu	=	Total gas savings for gas fryers (MMBtu)
1000	=	Converts watts to kilowatts
Days	=	Annual days of kitchen operation = 312 days[1]
$EFOOD_{Electric}$	=	ASTM energy to food for electric fryer = 167 Wh/lb

$EFOOD_{Gas}$	=	ASTM energy to food for gas fryer = 570 Btu/lb
$ElectricEFF_{Base}$	=	Cooking efficiency of baseline electric fryer = 75% for standard fryers = 70% for large vat fryers
$ElectricEFF_{ESTAR}$	=	Cooking efficiency of ENERGY STAR electric fryer = 83% for standard fryers = 80% for large vat fryers
FoodCooked	=	Food cooked per day = 150 lbs
$GasEFF_{Base}$	=	Cooking efficiency of baseline gas fryer = 35% for standard and large vat fryers
$GasEFF_{ESTAR}$	=	Cooking efficiency of ENERGY STAR gas fryer = 50% for standard and large vat fryers
Hours	=	Average daily hours of operation = 16 hours for standard fryers = 12 hours for large vat fryers
$IdleRateElectric_{Base}$	=	Idle energy rate of baseline electric fryer = 1200 W for standard fryers = 1350 W for large vat fryers
$IdleRateElectric_{ESTAR}$	=	Idle energy rate of ENERGY STAR electric fryer = 800W for standard fryers = 1100 for large vat fryer
$IdleRateGas_{Base}$	=	Idle energy rate of baseline gas fryer = 14,000 Btu/hr for standard fryers = 16,000 Btu/hr for large vat fryers
$IdleRateGas_{ESTAR}$	=	Idle energy rate of ENERGY STAR gas fryer = 9,000 Btu/hr for standard fryers = 12,000 Btu/hr for large vat fryers
$ProductionElectric_{Base}$	=	Production capacity of baseline electric fryer = 65 lb/hr for standard fryers = 100 lb/hr for large vat fryers
$ProductionElectric_{ESTAR}$	=	Production capacity of ENERGY STAR electric fryer = 70 lb/hr for standard fryers = 110 lb/hr for large vat fryers
$ProductionGas_{Base}$	=	Production capacity of baseline gas fryer = 60 lb/hr for standard fryers = 100 lb/hr for large vat fryers
$ProductionGas_{ESTAR}$	=	Production capacity of ENERGY STAR gas fryer = 65 lb/hr for standard fryers = 110 lb/hr for large vat fryers

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLFRYER	Energy Star Fryer

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLFRYER	1.00	1.00

Lifetimes

Lifetime is assumed as 12 years[2]

Measure Cost

Incremental costs are assumed to be as follows: [3]

Fuel	Fryer Type	Incremental Cost
Electric	Standard	$276
	Large vat	$1150
Gas	Standard	$1,860
	Large vat	$1,850

Footnotes

[1] Reduced from 365 days assumed in the ENERGY STAR calculator to account for seasonal operation and kitchens not operating every day. Assumes an average of 6 days per week operation.

[2] Based on ENERGY STAR calculator assumption.

[3] Based on ENERGY STAR Calculator assumption.

Commercial Steam Cooker

Measure Number: CI-CKE-STEAM a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

New measure

Referenced Documents

- ENERGY STAR CKE Calculator_Oct 2016
- ENERGY STAR_Commercial Steam Cookers_Program Requirements v1.2
- PGECOFST104 R6 Steam Cookers Commercial
- EVT_Steam Cooker_Analysis_May 2020_v2

Description

This measure involves the installation of an ENERGY STAR electric, natural gas, or propane commercial steam cooker. Energy savings are dependent on steam cooker pan capacity and corresponding maximum idle rate at heavy load cooking capacity. ENERGY STAR steam cookers consume less energy than conventional units because of improved insulation and a more efficient steam delivery system.

In order to qualify for participation, the installed ENERGY STAR steam cooker must meet the ENERGY STAR version 1.2 product specifications, effective August 1, 2003. The energy savings detailed in this characterization assume that the efficient equipment and baseline equipment have the same capacity (number of pans). Unless otherwise noted, the default values inputted into the energy savings algorithms are sourced from the "ENERGY STAR Commercial Kitchen Equipment Calculator - Steam Cooker Calculations (October 2016)".

Program Type

Calculation Type: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Midstream

Baseline Efficiencies

The baseline equipment is assumed to be a non-ENERGY STAR, conventional commercial steam cooker.

Efficient Equipment

The efficient equipment is an ENERGY STAR commercial steam cooker, meeting the ENERGY STAR version 1.2 qualifying critera.[1]

Energy Efficiency Requirements for Electric Steam Cookers

Pan Capacity	Heavy Load Cooking Energy Efficiency	Idle Rate (watts)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

Energy Efficiency Requirements for Gas Steam Cookers

Pan Capacity	Heavy Load Cooking Energy Efficiency	Idle Rate (watts)
3-pan	38%	6,250
4-pan	38%	8,350
5-pan	38%	10,400
6-pan and larger	38%	12,500

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / (Hours × Days)

Symbol Table

Water Savings

ΔCCF	$= ((Water_{Base} - Water_{EE}) \times Hours \times Days) / 748$

Symbol Table

Electric Energy Savings

ΔkWh	= ΔEnergy Savings (kWh) × Days
ΔEnergy Savings (kWh)	= (ΔIdle Energy + ΔPreheat Energy + ΔCooking Energy)
ΔIdle Energy	$= ((((1 - CSM_{\%Base}) \times Idle_{Base} + CSM_{\%Base} \times PC_{Base} \times E_{Food} / Eff_{Base}) \times (Hours - (Food / PC_{Base}) - (Preheat_{Number} \times 0.25))) - (((1 - CSM_{\%EE}) \times Idle_{EE} + CSM_{\%EE} \times PC_{EE} \times E_{Food} / Eff_{EE}) \times (Hours - (Food / PC_{EE}) - (Preheat_{Number} \times 0.25))))$
ΔPreheat Energy	$= (Preheat_{Number} \times Preheat_{Savings})$
ΔCooking Energy	$= ((1 / Eff_{Base}) - (1 / Eff_{EE})) \times Food \times E_{Food}$

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= ΔEnergy Savings (MMBtu) / 1,000,000 × Days

Where:

ΔCCF	=	Gross customer annual water savings for the measure
ΔCooking Energy	=	Energy savings associated with the steam cooker's primary cooking function, the duration when it is directly inputted energy into the food product
ΔEnergy Savings (kWh)	=	Electric daily kWh energy savings
ΔEnergy Savings (MMBtu)	=	Fossil fuel daily MMBtu energy savings
ΔIdle Energy	=	Energy savings associated with the steam cooker's idle operations, while it is maintaining or holding at a stabilized operating condition or temperature
ΔkW	=	Gross customer connected load kW demand savings
ΔkWh	=	Gross customer annual kWh energy savings

ΔMMBtu	=	Gross customer annual MMBtu energy savings
ΔPreheat Energy	=	Energy savings associated with the steam cooker's pre-heat cycle
0.25	=	Duration of the preheat cycle in hours[4]
1,000,000	=	Conversion factor from Btu to MMBtu
748	=	Constant to convert from gallons to CCF
$CSM_{\%Base}$	=	Percentage of time baseline steamer is in manual steam mode = 40%
$CSM_{\%EE}$	=	Percentage of time efficient steamer is in manual steam mode = 40%
Days	=	Number of days per year the commercial steam cooker is operated = 312 days[3]
E_{Food}	=	Amount of energy absorbed by the food during cooking = 0.0308 kW/lb for electric steam cookers = 105 Btu/lb for gas steam cookers
Eff_{Base}	=	Baseline steamer heavy load cooking efficiency = 30% for electric steam cookers = 15% for gas steam cookers
Eff_{EE}	=	Efficient steamer heavy load cooking efficiency = 50% for electric steam cookers = 38% for gas steam cookers
Food	=	Quantity of food cookers per day = 100 lbs/day
Hours	=	Daily operating hours per day = 12 hours
$Idle_{Base}$	=	Baseline steam cooker idle energy rate. See tables below for default values depending on equipment capacity (number of pans) and fuel type.
$Idle_{EE}$	=	Efficient steam cooker idle energy rate. See tables below for default values depending on equipment capacity (number of pans) and fuel type.
PC_{Base}	=	Baseline steam cooker production capacity. See tables below for default values depending on equipment capacity (number of pans) and fuel type.
PC_{EE}	=	Efficient steam cooker production capacity. See tables below for default values depending on equipment capacity (number of pans) and fuel type.
$Preheat_{Number}$	=	Number of preheat cycles per day = 1
$Preheat_{Savings}$	=	Preheat energy savings per preheat cycle = 0.5 kWh/day for electric steam cookers = 11,000 Btu/day for gas steam cookers
$Water_{Base}$	=	Water consumption rate of the baseline steam cooker in gallons per hour. See tables below for default values depending on equipment capacity (number of pans) and fuel type.
$Water_{EE}$	=	Water consumption rate of the efficient steam cooker in gallons per hour. See tables below for default values depending on equipment capacity (number of pans) and fuel type.

Default Algorithm Values

$Idle_{Base}$

Number of Pans	Gas Idle	Electric Idle
3	11,000	1.00
4	14,667	1.33
5	18,333	1.67
6	22,000	2.00
Unknown[2]	21,542	1.70

PC_{Base}

Number of Pans	Gas PC	Electric PC
per pan	23.3	23.3
3	69.9	69.9
4	93.2	93.2
5	116.5	116.5
6	139.8	139.8
Unknown[2]	136.9	118.8

$Idle_{EE}$

Number of Pans	Gas Idle	Electric Idle
3	6,250	0.40
4	8,333	0.53
5	10,417	0.67
6	12,500	0.80
Unknown[2]	12,240	0.68

PC_{EE}

Number of Pans	Gas PC	Electric PC
per pan	20.0	16.7
3	60.0	50.1
4	80.0	66.8
5	100.0	83.5
6	120.0	100.2
Unknown[2]	117.5	85.2

$Water_{Base}$

Number of Pans	Gas Water Rate (GPH)	Electric Water Rate (GPH)
per pan	5.83	5.83
3	17.49	17.49
4	23.32	23.32
5	29.15	29.15
6	34.98	34.98
Unknown[2]	34.25	29.73

Water$_{EE}$

Number of Pans	Gas Water Rate (GPH)	Electric Water Rate (GPH)
per pan	0.51	0.40
3	1.53	1.20
4	2.04	1.60
5	2.55	2.00
6	3.06	2.40
Unknown[2]	3.00	2.04

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLSTEAM	Energy Star Steam Cooker

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLSTEAM	1.00	1.00

Lifetimes

The expected measure life of a commercial steam cooker is 12 years.[5]

Measure Cost

The assumed incremental cost is $3400 for an electric steam cooker and $2270 for a natural gas steam cookers.[6]

Reference Tables

Deemed Energy and Demand Savings

	Electric Steam Cooker			Natural Gas / Propane Steam Cooker	
Number of Pans	ΔkWh Savings	ΔkW Savings	Water Savings (ccf)	ΔMMBtu Savings	Water Savings (ccf)
3	8,112	2.1667	81.5	68.3	79.9
4	10,546	2.8168	108.7	87.6	106.5
5	13,010	3.4749	135.9	106.8	133.1
6+	15,444	4.1250	163.1	126.1	159.8
Unknown	13,229	3.5334	138.6	123.7	156.4

Item Codes

Number of Pans	Electric Steam Cooker	Natural Gas Steam Cooker	Propane Steam Cooker
3	CKE-STEAM-E3	CKE-STEAM-NG3	CKE-STEAM-PG3
4	CKE-STEAM-E4	CKE-STEAM-NG4	CKE-STEAM-PG4
5	CKE-STEAM-E5	CKE-STEAM-NG5	CKE-STEAM-PG5
6+	CKE-STEAM-E6	CKE-STEAM-NG6	CKE-STEAM-PG6
Unknown	CKE-STEAM-EUNK	CKE-STEAM-NGUNK	CKE-STEAM-PUNK

Footnotes

[1] ENERGY STAR Product Specifications for Commercial Steam Cooker, v1.2, effective August 2003.

[2] The unknown cateogry is based on a weighted average of available products on the ENERGY STAR, "Commercial Steam Cookers Qualified Products List," as accessed on January 23, 2018

[3] The number of days per year is based on the assumption that the restaurant will be open six out of seven days per week.

[4] Pacific Gas and Electric, "Commercial Steam Cookers, Food Service Equipment Workpaper PGECOFST104 R6," 2016

[5] The measure life is sourced from the ENERGY STAR Commercial Kitchen Equipment Calculator - Steam Cooker Calculations (October 2016).

[6] The incremental cost is sourced from the ENERGY STAR Commercial Kitchen Equipment Calculator - Steam Cooker Calculations (October 2016).

ENERGY STAR Combination Oven

Measure Number: CI-KTN-COMB a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

This is version one of the TRM characterization.

Referenced Documents

Linked below are the ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2, which defines the efficient and eligible equipment and the Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment, from which impact algorithms and assumptions are referenced.

- Commercial Ovens Final Version 2.2
- commercial_kitchen_equipment_calculator_Combi

Description

A combination oven is a device that combines the function of hot air convection (oven mode), saturated and superheated steam heating (steam mode), and combination convection/steam mode for moist heating, to perform steaming, baking, roasting, rethermalizing, and proofing of various food products. In general, the term combination oven is used to describe this type of equipment, which is self-contained. The combination oven is also referred to as a combination oven/steamer, combi or combo.

Half- and full-size gas combination ovens with a pan capacity ≥ 6; and half- and full-size electric combination ovens with a pan capacity ≥ 5 and ≤ 20 are eligible for ENERGY STAR certification by achieving both convection mode and steam mode idle and cooking energy efficiency levels. Cooking energy efficiency represents the amount of energy absorbed by the food product compared to the total energy used by the oven during the cooking process. The idle energy rate represents the energy used by the oven while it is maintaining or holding at a stabilized temperature.

Combination ovens are commonly classified and referred to by size category:

Half-Size Combination Oven: A combination oven capable of accommodating a single 12 x 20 x 2 ½-inch steam table pan per rack position, loaded from front-to-back or lengthwise.

Full-Size Combination Oven: A combination oven capable of accommodating two 12 x 20 x 2 ½-inch steam table pans per rack position, loaded side by side, from front-to-back or lengthwise.

2/3-Size Combination Oven: A combination oven capable of accommodating a single 12 x 10 x 2 ½-inch steam table pan per rack position, loaded from front-to-back or lengthwise.

Note: 2/3-size combination ovens are ineligible for ENERGY STAR certification, as are gas (natural or propane) combination ovens with a pan capacity of < 6 and electric combination ovens with a pan capacity < 5 and > 20.

This measure is an eligible combination oven that has achieved ENERGY STAR certification by meeting Version 2.2 eligibility criteria.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Mid stream

This characterization was developed for measure implementation by way of a midstream program with commercial kitchen equipment dealers.

Units rebated through the program will map to one of the fifteen products summarized in the Reference Tables section below.

Baseline Efficiencies

The baseline condition is a combination oven (electric, natural gas, or propane) that is not ENERGY STAR certified.

Efficient Equipment

The efficient condition is a combination oven (electric, natural gas, or propane) that has achieved ENERGY STAR certification by meeting Version 2.2 eligibility criteria.[1]

Algorithms

Electric Demand Savings

Intuitively and as suggested by the algorithm for energy savings, instantaneous electric demand is not constant during the operation of a combination oven - demand is higher during times of cooking compared to idle. However, in an upstream program model, specific unit use patterns will be not be known. To align with the savings loadshape choice for commercial cooking equipment - 90b Restaurant Indoor Lighting - which assumes consistent instantaneous demand savings, demand savings for a combination oven is estimated as the average over the entire operational period.

ΔkW	$= ((Idle_{Base} - Idle_{EStar}) + (Cooking_{Base} - (Cooking_{EStar})) / 1,000 / Hours$

Symbol Table

Electric Energy Savings

ΔkWh	$= ((Idle_{Base} - Idle_{EStar}) + (Cooking_{Base} - Cooking_{EStar})) / 1,000 \times Days$
$Idle_{Base}$	$= ConvectionIdle_{Base} + SteamIdle_{Base}$
$Cooking_{Base}$	$= ConvectionCooking_{Base} + SteamCooking_{Base}$
$Idle_{EStar}$	$= ConvectionIdle_{EStar} + SteamIdle_{EStar}$
$Cooking_{EStar}$	$= ConvectionCooking_{EStar} + SteamCooking_{EStar}$
$IdleRate_{EStar}$	$= A \times Pans + B$
$SteamCooking_{Base}$	$= Steam \times Food \times E_{Food} / Eff_{Base}$
$ConvectionCooking_{Base}$	$= Convection \times Food \times E_{Food} / Eff_{Base}$
$SteamCooking_{EStar}$	$= Steam \times Food \times E_{Food} / Eff_{EStar}$
$ConvectionCooking_{EStar}$	$= Convection \times Food \times E_{Food} / Eff_{EStar}$
$SteamIdle_{Base}$	$= Steam \times IdleRate_{Base} \times (Hours - (Food / Capacity_{Base}))$
$ConvectionIdle_{Base}$	$= Convection \times IdleRate_{Base} \times (Hours - (Food / Capacity_{Base}))$
$SteamIdle_{EStar}$	$= Steam \times IdleRate_{EStar} \times (Hours - (Food / Capacity_{EStar}))$
$ConvectionIdle_{EStar}$	$= Convection \times IdleRate_{EStar} \times (Hours - (Food / Capacity_{EStar}))$

Symbol Table

Fossil Fuel Savings

ΔMMBtu $= ((Idle_{Base} - Idle_{EStar}) + (Cooking_{Base} - Cooking_{EStar})) / 1{,}000{,}000 \times Days$

Symbol Table

Water Savings
No water savings are expected.

Where:

ΔkW = Gross electric demand savings (kW).

ΔkWh = Gross annual electric energy savings (kWh).

ΔMMBtu = Gross annual natural gas or propane energy savings (MMBtu).

1,000,000 = Conversion factor, from Btu to MMBtu.

1,000 = Conversion factor, from W to kW.

A = Multiplier, dependent on energy source and operation mode. Units are Watts (electric equipment) or Btu/hour (natural gas and propane equipment).

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Energy Source	Operation Mode	A[3]
Electric	Steam	133 Watts
	Convection	80 Watts
Gas*	Steam	200 Btu/hour
	Convection	150 Btu/hour

*Includes both natual gas and propane

B = Adder, dependent on energy source and operation mode. Units are Watts (electric equipment) or Btu/hour (natural gas and propane equipment).

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Energy Source	Operation Mode	B[3]
Electric	Steam	640 Watts
	Convection	498.9 Watts
Gas*	Steam	6,511 Btu/hour
	Convection	5,425 Btu/hour

*Includes both natual gas and propane

$Capacity_{Base}$ = Production capacity of baseline unit. Units are in lbs/hour. Dependent on energy source, operation mode and pan capacity.

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Energy Source	Operation Mode	Pans	$Capacity_{Base}$[4]
Electric	Steam	< 15	126
		≥ 15	295
	Convection	< 15	79
		≥ 15	166
Gas*	Steam	< 15	195
		≥15 and <30	211
		≥ 30	579
	Convection	< 15	125
		≥15 and <30	176
		≥ 30	392

*Includes both natual gas and propane

$Capacity_{EStar}$ = Production capacity of ENERGY STAR certified unit. Units are in lbs/hour. Dependent on energy source, operation mode and pan capacity.

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Energy Source	Operation Mode	Pans	$Capacity_{EStar}$[4]
Electric	Steam	< 15	177
		≥ 15	349
	Convection	< 15	119
		≥ 15	201
Gas*	Steam	< 15	172
		≥15 and <30	277
		≥ 30	640
	Convection	< 15	124
		≥15 and <30	210
		≥ 30	394

*Includes both natual gas and propane

Convection = Percentage of food cooked in convection mode.

= 50%[4]

$ConvectionCooking_{Base}$ = Daily cooking energy consumption of baseline unit while operating in convection mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$ConvectionCooking_{EStar}$ = Daily cooking energy consumption of ENERGY STAR certified unit while operating in convection mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$ConvectionIdle_{Base}$ = Daily idle energy consumption of baseline unit while operating in convection mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$ConvectionIdle_{EStar}$ = Daily idle energy consumption of ENERGY STAR certified unit while operating in convection mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$Cooking_{Base}$ = Daily cooking energy consumption of baseline unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$Cooking_{EStar}$ = Daily cooking energy consumption of ENERGY STAR certified unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

Days = Annual days the convection oven is in operation.

= 312 days/year[5]

E_{Food} = Amount of energy absorbed by the food during cooking. Units are Watts-hours/lbs (electric equipment) or Btu/lbs (natural gas and propane equipment). Dependent on energy source and operation mode.

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Energy Source	Operation Mode	E_{Food}[4]
Electric	Steam	30.8 Wh/lbs
	Convection	73.2 Wh/lbs

Gas*	Steam	105 Btu/lbs
	Convection	250 Btu/lbs

*Includes both natual gas and propane

Eff_{Base} = Cooking energy efficiency of baseline unit. A measure of the quantity of energy imparted to the specified load, expressed as a percentage of energy consumed by the oven during the cooking event. Dependent on energy source and operation mode.

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Energy Source	Operation Mode	Eff_{Base} [6]
Electric	Steam	49%
	Convection	72%
Gas*	Steam	39%
	Convection	52%

*Includes both natual gas and propane

Eff_{EStar} = Cooking energy efficiency of ENERGY STAR certified unit. A measure of the quantity of energy imparted to the specified load, expressed as a percentage of energy consumed by the oven during the cooking event. Dependent on energy source and operation mode.

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Energy Source	Operation Mode	Eff_{EStar} [3]
Electric	Steam	55%
	Convection	76%
Gas*	Steam	41%
	Convection	56%

*Includes both natual gas and propane

Food = Pounds of food cooked per day (lbs). Dependent on energy source and pan capacity.

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Energy Source	Pan Capacity	Food[4]
Electric	< 15	200
	≥ 15	250
Gas*	< 15	200
	≥15 and <30	250
	≥ 30	400

*Includes both natual gas and propane

Hours = Operating hours per day.

= 12 hours/day.[2]

$Idle_{Base}$ = Daily total idle energy consumption of baseline unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$Idle_{EStar}$ = Daily total idle energy consumption of ENERGY STAR certified unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$IdleRate_{Base}$ = Idle energy rate the baseline unit. Idle energy rate is the rate of oven energy consumption while it is maintaining or holding at a stabilized operating condition or temperature. Also called standby energy rate. Units are Watts (electric equipment) or Btu/hour (natural gas and propane equipment). Dependent on energy source, operation mode and pan capacity.

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Energy Source	Operation Mode	Pans	$Idle_{Base}$ [6]
Electric	Steam	< 15	5,260 (Watts)
		≥ 15	8,710 (Watts)
	Convection	< 15	1,320 (Watts)
		≥ 15	2,280 (Watts)
Gas*	Steam	< 15	18,656 (Btu/hour)
		≥15 and <30	24,562 (Btu/hour)
		≥ 30	43,300 (Btu/hour)
	Convection	< 15	8,747 (Btu/hour)
		≥15 and <30	7,823 (Btu/hour)
		≥ 30	13,000 (Btu/hour)

*Includes both natual gas and propane

$IdleRate_{EStar}$ = Idle energy rate of ENERGY STAR certified unit. Idle energy rate is the rate of oven energy consumption while it is maintaining or holding at a stabilized operating condition or temperature. Also called standby energy rate. Units are Watts (electric equipment) or Btu/hour (natural gas and propane equipment). Dependent on energy source, operation mode and pan capacity.

Pans = Pan capacity, the number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.

In addition to energy source and operation mode, ENERGY STAR specifications for establishing cooking energy efficiency and idle energy rate requirements are determined by pan capacity via a continuous function.

For the purpose of claiming savings, pan capacity ranges and deemed values (for use in algoithms) are used per the following table. This approach strikes a balance with granularity in savings and implementability.

Note that capacity ranges and deemed values do not necessarily follow a pattern - this is due to the fact that assignments were made based on the actual list of ENERGY STAR certified equipment, which is more heavily weighted in certian ranges and capacities.

Energy Source	Pan Capacity Range	Pans
Electric	≥ 5 and ≤ 8	6
	> 8 and ≤ 10	10
	> 10 and ≤ 12	12
	> 12 and ≤ 17	14
	> 17 and ≤ 20	20
Gas*	≥ 6 and ≤ 12	9
	> 12 and ≤ 18	14
	> 18 and ≤ 24	20
	> 24 and ≤ 32	32
	> 32 and ≤ 40	40

*Includes both natual gas and propane

Steam = Percentage of food cooked in steam mode.

= 50%[4]

$SteamCooking_{Base}$ = Daily cooking energy consumption of baseline unit while operating in steam mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$SteamCooking_{EStar}$ = Daily cooking energy consumption of ENERGY STAR certified unit while operating in steam mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$SteamIdle_{Base}$ = Daily idle energy consumption of baseline unit while operating in steam mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$SteamIdle_{EStar}$	=	Daily idle energy consumption of ENERGY STAR certified unit while operating in steam mode. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

Mid-Life Savings Adjustment

No mid-life savings adjustments are applicable to this measure.

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLOCOMB	Energy Star Commercial Combination Oven

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLOCOMB	1.00	1.00

Lifetimes

Equipment lifetime is 12 years.[7]

Measure Cost

The incremental cost for an ENERGY STAR certified unit is $0.[8]

Operation and Maintenance Cost Adjustments

No operation and maintenance cost adjustments are applicable to this measure.

Reference Tables

The following table shows the algorithm outcomes and correcsponding ItemCode:

For full derivation of values, see Referenced Document commercial_kitchen_equipment_calculator_Combi

Energy Source	Pan Capacity Range	Pans	$ConvectionIdle_{Base}$	$SteamIdle_{Base}$	$ConvectionIdle_{EStar}$	$SteamIdle_{EStar}$	$ConvectionCooking_{Base}$	$SteamCooking_{Base}$	$ConvectionCooking_{EStar}$	$SteamCooking_{EStar}$	$Idle_{Base}$	$Idle_{EStar}$	$Cooking_{Base}$	$Cooking_{EStar}$	ΔkWh	ΔkW	ΔMMBtu	ItemCode
Electric	> 5 and ≤ 8	6	6,249.1	27,385.4	5,050.3	7,815.6	10,166.7	6,285.7	9,631.6	5,600.0	33,634.5	12,865.8	16,452.4	15,231.6	6,860.7	1.83246	N/A	CI-KTN-CMBI-E06
	> 8 and ≤ 10	10	6,249.1	27,385.4	6,701.4	10,707.0	10,166.7	6,285.7	9,631.6	5,600.0	33,634.5	17,408.4	16,452.4	15,231.6	5,443.4	1.45391	N/A	CI-KTN-CMBI-E10
	> 10 and ≤ 12	12	6,249.1	27,385.4	7,526.9	12,152.7	10,166.7	6,285.7	9,631.6	5,600.0	33,634.5	19,679.6	16,452.4	15,231.6	4,734.8	1.26464	N/A	CI-KTN-CMBI-E12
	> 12 and ≤ 17	14	6,249.1	27,385.4	8,352.5	13,598.4	10,166.7	6,285.7	9,631.6	5,600.0	33,634.5	21,950.9	16,452.4	15,231.6	4,026.2	1.07537	N/A	CI-KTN-CMBI-E14
	> 17 and ≤ 20	20	11,963.1	48,569.3	11,287.6	18,618.1	12,708.3	7,857.1	12,039.5	7,000.0	60,532.5	29,905.6	20,565.5	19,039.5	10,031.7	2.67940	N/A	CI-KTN-CMBI-E20
Natural Gas	> 6 and ≤ 12	9	45,484.400	102,368.821	35,186.290	45,034.023	48,076.923	26,923.077	44,642.857	25,609.756	147,853.221	80,220.314	75,000.000	70,252.613	N/A	N/A	22.583	CI-KTN-CMBI-NG09
	> 12 and ≤ 18	14	45,484.400	102,368.821	39,081.452	50,452.628	48,076.923	26,923.077	44,642.857	25,609.756	147,853.221	89,534.080	75,000.000	70,252.613	N/A	N/A	19.677	CI-KTN-CMBI-NG14
	> 18 and ≤ 24	20	41,381.892	132,821.052	45,535.119	58,322.769	60,096.154	33,653.846	55,803.571	32,012.195	174,202.944	103,857.888	93,750.000	87,815.767	N/A	N/A	23.799	CI-KTN-CMBI-NG20
	> 24 and ≤ 32	32	71,367.347	244,843.178	56,159.645	73,431.313	96,153.846	53,846.154	89,285.714	51,219.512	316,210.525	129,590.957	150,000.000	140,505.226	N/A	N/A	61.188	CI-KTN-CMBI-NG32
	> 32 and ≤ 40	40	71,367.347	244,843.178	62,750.508	82,531.313	96,153.846	53,846.154	89,285.714	51,219.512	316,210.525	145,281.820	150,000.000	140,505.226	N/A	N/A	56.292	CI-KTN-CMBI-NG40
Propane	> 6 and ≤ 12	9	45,484.400	102,368.821	35,186.290	45,034.023	48,076.923	26,923.077	44,642.857	25,609.756	147,853.221	80,220.314	75,000.000	70,252.613	N/A	N/A	22.583	CI-KTN-CMBI-P09
	> 12 and ≤ 18	14	45,484.400	102,368.821	39,081.452	50,452.628	48,076.923	26,923.077	44,642.857	25,609.756	147,853.221	89,534.080	75,000.000	70,252.613	N/A	N/A	19.677	CI-KTN-CMBI-P14
	> 18 and ≤ 24	20	41,381.892	132,821.052	45,535.119	58,322.769	60,096.154	33,653.846	55,803.571	32,012.195	174,202.944	103,857.888	93,750.000	87,815.767	N/A	N/A	23.799	CI-KTN-CMBI-P20
	> 24 and ≤ 32	32	71,367.347	244,843.178	56,159.645	73,431.313	96,153.846	53,846.154	89,285.714	51,219.512	316,210.525	129,590.957	150,000.000	140,505.226	N/A	N/A	61.188	CI-KTN-CMBI-P32
	> 32 and ≤ 40	40	71,367.347	244,843.178	62,750.508	82,531.313	96,153.846	53,846.154	89,285.714	51,219.512	316,210.525	145,281.820	150,000.000	140,505.226	N/A	N/A	56.292	CI-KTN-CMBI-P40

Footnotes

[1] See complete qualification criteria in reference file ***Commercial Ovens Final Version 2.2***. See Referenced Document Commercial Ovens Final Version 2.2.

[2] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated February 2015), which references ***EPA & Food Service Technology Center (FSTC) research on average use, 2013***. See Referenced Document commercial_kitchen_equipment_calculator_Combi.

[3] As specified in ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2. See Referenced Document Commercial Ovens Final Version 2.2.

[4] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated February 2015). See Referenced Document commercial_kitchen_equipment_calculator_Combi.

[5] Assumes operation 6 out of 7 days per week. 6 days/week x 52 week/year = 312 days/year.

[6] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated February 2015), which references **EPA research on available models, 2013**. See Referenced Document commercial_kitchen_equipment_calculator_Combi.

[7] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated February 2015), which references **FSTC research on available models, 2009**. See Referenced Document commercial_kitchen_equipment_calculator_Combi.

[8] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated February 2015), which references ***Difference between a similar ENERGY STAR and non-qualifying model, EPA research using AutoQuotes, 2013***. See Referenced Document commercial_kitchen_equipment_calculator_Combi.

ENERGY STAR Convection Oven

Measure Number: CI-KTN-CONV a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

This is version one of the TRM characterization.

Referenced Documents

Linked below are the ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2, which defines the efficient and eligible equipment and the Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment, from which impact algorithms and assumptions are referenced.

- ENERGY STAR CKE Calculator_Oct 2016
- Commercial Ovens Final Version 2.2
- commercial_kitchen_equipment_calculator_Convection

Description

Commercial convection ovens are the most widely used appliances in the foodservice industry. These are the workhorses of the commercial kitchen, with a wide variety of uses from baking and roasting to warming and reheating. In addition to traditional uses, convection ovens are used for nearly all types of food preparation, including foods typically prepared using other types of appliances (e.g., griddles, fryers, etc.). Commercial ovens that have earned the ENERGY STAR are about 20 percent more energy efficient than standard models.

A convection oven is general-purpose oven that cooks food by forcing hot dry air over the surface of the food product. The rapidly moving hot air strips away the layer of cooler air next to the food and enables the food to absorb the heat energy. For consistency with ENERGY STAR definitions, convection ovens do not include ovens that have the ability to heat the cooking cavity with saturated or superheated steam. However, convection ovens may have moisture injection capabilities (e.g., baking ovens and moisture-assist ovens). Ovens that include a hold feature are eligible under this specification as long as convection is the only method used to fully cook the food.

Convection ovens are classified by size category:

Half-Size Convection Oven: A convection oven that is capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch.

Full-Size Convection Oven: A convection oven that is capable of accommodating standard full-size sheet pans measuring 18 x 26 x 1-inch.

This measure is a convection oven that has achieved ENERGY STAR certification by meeting Version 2.2 eligibility criteria.

Full- and half-size electric convection ovens, and full-size gas (natural gas or propane) convection ovens are eligible to earn ENERGY STAR certification.

Certification is earned by meeting minimum cooking energy efficiency, as well as a maximum idle energy rates. Cooking energy efficiency represents the amount of energy absorbed by the food product compared to the total energy used by the oven during the cooking process. The idle energy rate represents the energy used by the oven while it is maintaining or holding at a stabilized temperature.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Mid stream

This characterization was developed for measure implementation by way of a midstream program with commercial kitchen equipment dealers.

Units rebated through the program will map to one of the four products summarized in the Reference Tables section below.

Baseline Efficiencies

The baseline condition is a convection oven (electric, natural gas, or propane) that is not ENERGY STAR certified.

Efficient Equipment

The efficient condition is a convection oven (electric, natural gas, or propane) that has achieved ENERGY STAR certification by meeting Version 2.2 eligibility criteria.[1]

Algorithms

Electric Demand Savings

Intuitively and as suggested by the algorithm for energy savings, instantaneous electric demand is not constant during the operation of a convection oven - demand is higher during times of cooking compared to idle. However, in an upstream program model, specific unit use patterns will be not be known. To align with the savings loadshape choice for commercial cooking equipment - 90b Restaurant Indoor Lighting - which assumes consistent instantaneous demand savings, demand savings for a convection oven is estimated as the average over the entire operational period.

$\Delta kW = ((Idle_{Base} - Idle_{EStar}) + (Cooking_{Base} - (Cooking_{EStar})) / 1{,}000 / Hours$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((Idle_{Base} - Idle_{EStar}) + (Cooking_{Base} - Cooking_{EStar})) / 1{,}000 \times Days$

$Idle_{Base} = IdleRate_{Base} \times (Hours - (Food / Capacity_{Base}))$

$Cooking_{Base} = Food \times E_{Food} / Eff_{Base}$

$Idle_{EStar} = IdleRate_{EStar} \times (Hours - (Food / Capacity_{EStar}))$

$Cooking_{EStar} = Food \times E_{Food} / Eff_{EStar}$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu = ((Idle_{Base} - Idle_{EStar}) + (Cooking_{Base} - Cooking_{EStar})) / 1{,}000{,}000 \times Days$

Symbol Table

Water Savings

No water savings are expected.

Where:

ΔkW	=	Gross electric demand savings (kW).
ΔkWh	=	Gross annual electric energy savings (kWh).
ΔMMBtu	=	Gross annual natural gas or propane energy savings (MMBtu).
1,000,000	=	Conversion factor, from Btu to MMBtu.
1,000	=	Conversion factor, from W to kW.
$Capacity_{EStar}$	=	Production capacity of ENERGY STAR certified unit. Units are in lbs/hour.
		=

Energy Source	Size Class	$Capacity_{EStar}$ [3]
Electric	Half-Size	50
	Full-Size	90
Gas*	Full-Size	86

*Includes both natual gas and propane

$Capacity_{Base}$ = Production capacity of baseline unit. Units are in lbs/hour.

=

Energy Source	Size Class	$Capacity_{Base}$ [3]
Electric	Half-Size	45
	Full-Size	90
Gas*	Full-Size	83

*Includes both natual gas and propane

$Cooking_{Base}$ = Daily cooking energy consumption of baseline unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$Cooking_{EStar}$ = Daily cooking energy consumption of ENERGY STAR certified unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

Days = Annual days the convection oven is in operation.

= 312 days/year[4]

E_{Food} = Amount of energy absorbed by the food during cooking. Units are Watts-hours/lbs (electric equipment) or Btu/lbs (natural gas and propane equipment).

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Energy Source	E_{Food} [3]
Electric	73.2 Wh/lbs
Gas*	250 Btu/lbs

*Includes both natual gas and propane

Eff_{Base} = Cooking energy efficiency of baseline unit. A measure of the quantity of energy imparted to the specified load, expressed as a percentage of energy consumed by the oven during the cooking event.

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Energy Source	Size Class	Eff_{Base} [3]
Electric	Half-Size	68%
	Full-Size	65%
Gas*	Full-Size	44%

*Includes both natual gas and propane

Eff_{EStar} = Cooking energy efficiency of ENERGY STAR certified unit. A measure of the quantity of energy imparted to the specified load, expressed as a percentage of energy consumed by the oven during the cooking event.

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Energy Source	Size Class	Eff_{EStar} [5]
Electric	Half-Size	71%
	Full-Size	71%
Gas*	Full-Size	46%

*Includes both natual gas and propane

Food = Pounds of food cooked per day (lbs).

= 100 lbs.[3]

Hours = Operating hours per day.

= 12 hours/day.[2]

$Idle_{Base}$ = Daily idle energy consumption of baseline unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$Idle_{EStar}$ = Daily idle energy consumption of ENERGY STAR certified unit. Units are Watt-hours (electric equipment) or Btu (natural gas and propane equipment).

$IdleRate_{EStar}$ = Idle energy rate of ENERGY STAR certified unit. Idle energy rate is the rate of oven energy consumption while it is maintaining or holding at a stabilized operating condition or temperature. Also called standby energy rate. Units are Watts (electric equipment) or Btu/hour (natural gas and propane equipment).

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Energy Source	Size Class	$Idle_{EStar}$ [5]
Electric	Half-Size	1,000 (Watts)
	Full-Size	1,600 (Watts)
Gas*	Full-Size	12,000 (Btu/hour)

*Includes both natual gas and propane

$IdleRate_{Base}$ = Idle energy rate the baseline unit. Idle energy rate is the rate of oven energy consumption while it is maintaining or holding at a stabilized operating condition or temperature. Also called standby energy rate. Units are Watts (electric equipment) or Btu/hour (natural gas and propane equipment).

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Energy Source	Size Class	$Idle_{Base}$ [6]
Electric	Half-Size	1,030 (Watts)
	Full-Size	2,000 (Watts)
Gas*	Full-Size	15,100 (Btu/hour)

*Includes both natual gas and propane

Mid-Life Savings Adjustment

No mid-life savings adjustments are applicable to this measure.

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLOCONV Energy Star Commercial Convection Oven

Tracks [Base Track]

6013UPST [is base track] Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over

Upstream - Commercial	6013UPST	CKLOCONV	1.00	1.00	

Lifetimes

Equipment lifetime is 12 years.[7]

Measure Cost

The incremental cost for an ENERGY STAR certified unit is $388 for an electric unit and $170 for a gas unit.[8]

Operation and Maintenance Cost Adjustments

No operation and maintenance cost adjustments are applicable to this measure.

Reference Tables

The following table shows the algorithm outcomes and correcsponding ItemCode:

Energy Source	Size Class	$Idle_{Base}$	$Idle_{EStar}$	$Cooking_{Base}$	$Cooking_{EStar}$	ΔkW	ΔkWh	ΔMMBtu	ItemCode
Electric	Full-Size	21,777.8 Wh	17,422.2 Wh	11,261.5 Wh	10,309.9 Wh	0.44227	1,655.9	N/A	CI-KTN-CONV-EFUL
	Half-Size	10,071.1 Wh	10,000.0 Wh	10,764.7 Wh	10,309.9 Wh	0.04383	164.1	N/A	CI-KTN-CONV-EHAL
Natural Gas	Full-Size	163,007.229 Btu	130,046.512 Btu	56,818.182 Btu	54,347.826 Btu	N/A	N/A	11.054	CI-KTN-CONV-NGFL
Propane	Full-Size	163,007.229 Btu	130,046.512 Btu	56,818.182 Btu	54,347.826 Btu	N/A	N/A	11.054	CI-KTN-CONV-PFUL

Footnotes

[1] See complete qualification criteria in reference file ***Commercial Ovens Final Version 2.2***. See Referenced Document Commercial Ovens Final Version 2.2.

[2] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references ***EPA & Food Service Technology Center (FSTC) research on average use, 2013***. See Referenced Document commercial_kitchen_equipment_calculator_Convection.

[3] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016). See Referenced Document commercial_kitchen_equipment_calculator_Convection.

[4] Assumes operation 6 out of 7 days per week. 6 days/week x 52 week/year = 312 days/year.

[5] As specified in ENERGY STAR® Program Requirements Product Specification for Commercial Ovens, Eligibility Criteria Version 2.2. See Referenced Document Commercial Ovens Final Version 2.2.

[6] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references **EPA research on available models, 2013**. See Referenced Document commercial_kitchen_equipment_calculator_Convection.

[7] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references **FSTC research on available models, 2009**. See Referenced Document commercial_kitchen_equipment_calculator_Convection.

[8] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references ***Difference between a similar ENERGY STAR and non-qualifying model, EPA research using AutoQuotes, 2013***. See Referenced Document commercial_kitchen_equipment_calculator_Convection.

ENERGY STAR Griddle

Measure Number: CI-KTN-GRID a
Portfolio: EVT TRM Portfolio 2020-06
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

New Measure

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- commercial_kitchen_equipment_calculator_Griddle
- ENERGY STAR Commercial Griddles Specification v1.2
- DOE - Energy Savings Potential RDD Opportunities for Comm Bldg Appliances_2015
- California Public Utilities Commission MeasureDataSpec - Comm Griddle
- ENERGY STAR certified-commercial-griddles_2020-06-29
- ENERGY STAR Commercial Griddle Analysis 2020

Description

This measure applies to single-sided (electric or gas fired) and double-sided (electric and dual fuel) ENERGY STAR griddles installed in a commercial kitchen.

A commercial griddle is as an appliance designed for cooking food in oil or its own juices by direct contact with a thermostatically controlled hot surface. Single-Sided griddles consist of one bottom plate and are fired by either electric or gas (natural or propane). In addition to the bottom plate, Double-Sided Commercial Griddles have an upper plate which swings down over the food, cooking it on both sides. One type of these griddles have a gas-fired lower plate and an electric top plate and are therefore considered Dual Fuel. The other type of Double-Sided griddles are entirely electric.

Compared to standard equipment, ENERGY STAR qualified commercial griddles have lower Idle Energy Rates, greater Production Capacity and higher Cooking Efficiency, which results in less wasted energy.

Program Type

Calculation Type: Market Opportunity - TOS

Program Delivery / Implementation Type: Midstream

Baseline Efficiencies

The baseline equipment is an existing single-sided (natural gas or electric) or double-sided (dual fuel or electric) griddle that's not ENERGY STAR certified and is at end of use.

Efficient Equipment

To qualify for this measure the installed equipment must be a single or double-sided gas or electric ENERGY STAR griddle with a tested heavy load Cooking Energy Efficiency of at least 70 % (electric), 38 % (gas) and a Normalized Idle Energy Rate less than or equal to 2,650 Btu/hr / ft^2 (gas) or 320 W / ft^2 (electric) of cooking surface. ENERGY STAR Product testing must be performed in accordance with ASTM F1275 and ASTM F1605, the Standard Test Methods for Single and Double-sided Griddles, respectively.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / (Hours x Days)

Symbol Table

Electric Energy Savings

For double-sided, dual fuel griddles, assume that half of the MMBtu savings calculated according to the algorithm above are gas (natural or propane) savings and half are electric savings[3].

ΔkWh	= (ΔIdleDailyWh + ΔCookingDailyWh) x Days / 1,000
ΔIdleDailyWh	= (IdleRateElectric$_{BASE}$ x Area x (Hours – (LB/(Capacity$_{BASE}$ x Area)))) – (IdleRateElectric$_{ENERGYSTAR}$ x Area x (Hours – (LB/(Capacity$_{ENERGYSTAR}$ x Area))))
ΔCookingDailyWh	= (LB x EFOOD$_{ELECTRIC}$/Eff$_{BASE}$) - (LB x EFOOD$_{ELECTRIC}$/Eff$_{ESTAR}$)
ΔkWh$_{Dual Fuel}$	= (ΔMMBtu x 50%) x 293

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= (ΔIdleDailyBtu + ΔCookingDailyBtu) x Days / 1,000,000
ΔMMBtu$_{Dual Fuel}$	= ΔMMBtu x 50%
ΔIdleDailyBtu	= (IdleRateGas$_{BASE}$ x Area x (Hours – (LB/(Capacity$_{BASE}$ x Area))))- (IdleRateGas$_{ESTAR}$ x Area x (Hours – (LB/(Capacity$_{ENERGY STAR}$ x Area))))
ΔCookingDailyBtu	= (LB x EFOOD$_{GAS}$/Eff$_{BASE}$) - (LB x EFOOD$_{GAS}$/Eff$_{ESTAR}$)

Where:

ΔCookingDailyBtu	=	Gross Daily Gas Energy Savings, while *in Cooking mode* (Btu).
ΔCookingDailyWh	=	Gross Daily Electric Energy Savings, while *in Cooking mode* (Wh).
ΔIdleDailyBtu	=	Gross Daily Gas Energy Savings, while *in Idle mode* (Btu).
ΔIdleDailyWh	=	Gross Daily Electric Energy Savings, *in Idle mode* (Wh).
ΔkW	=	Gross Electric Demand Savings (kW). *For Deemed values, please see the Reference Table.*
ΔkWh$_{Dual Fuel}$	=	Gross Annual Electric Energy Savings, ***Dual Fuel*** (kWh). *For Deemed values, please see the Reference Table.*
ΔkWh	=	Gross Annual Electric Energy Savings, ***Electric single-side & Electric double-sided*** (kWh). *For Deemed values, please see the Reference Table.*
ΔMMBtu$_{Dual Fuel}$	=	Gross Annual Natural Gas or Propane Energy Savings for the Gas portion of the ***Dual Fuel*** Griddles (MMBtu). *For Deemed values, please see the Reference Table.*
ΔMMBtu	=	Gross Annual Natural Gas or Propane Energy Savings for ***Single-Sided Gas*** Griddles (MMBtu). *For Deemed values, please see the Reference Table*
1,000,000	=	Conversion factor, from Btu to MMBtu.

1,000	=	Conversion factor, from W to kW.
293	=	Conversion factor, from MMBtu to kWh.
50%	=	Savings split between electric and gas for Dual Fuel, Double-Sided Griddles[3].
Area	=	Area of the bottom cooking surface (ft^2) = 6 ft^2 [2]
$Capacity_{BASE}$	=	Production Capacity of a baseline unit[4]. Energy Source / (lbs/hr/sq ft): Electric 5.83; Gas * 4.17 * *Includes both natual gas and propane*
$Capacity_{ENERGYSTAR}$	=	Production Capacity of ENERGY STAR[5] certified unit. Energy Source / (lbs/hr/sq ft): Electric 6.67; Gas * 7.50; Double-Sided, Electric 8.17[6] * *Includes both natual gas and propane*
Days	=	Annual days the griddle is in operation. = 312 days[1]
Eff_{BASE}	=	Cooking Energy Efficiency of a baseline griddle[4]. This is the ratio of energy absorbed by the food product to the total energy supplied to the griddle during cooking. Electric = 65% Gas = 32%
Eff_{ESTAR}	=	Cooking Energy Efficiency of an ENERGY STAR certified griddle[5]. This is the ratio of energy absorbed by the food product to the total energy supplied to the griddle during cooking. Electric = 70% Gas = 38% Double-Sided, Electric Only = 75%[7]
$EFOOD_{ELECTRIC}$	=	Amount of energy absorbed by the food during cooking[2]. = 139 Wh/lb
$EFOOD_{GAS}$	=	Amount of energy absorbed by the food during cooking[2]. *Includes both natual gas and propane.* = 475 Btu/lb
Hours	=	Average Operating Hours per Day = 12 hours / day[2]
$IdleRateElectric_{BASE}$	=	*Normalized* Idle Energy Rate of the baseline electric* models[4]. = 400 W/ft^2 **includes single and double side griddles*
$IdleRateElectric_{ENERGYSTAR}$	=	*Normalized* Idle Energy Rate of the ENERGY STAR certified electric model[5]. # of sides / Idle Rate: Single-Sided 320 W/ft^2; Double-Sided 293 W/ft^2[8]
$IdleRateGas_{BASE}$	=	*Normalized* Idle Energy Rate of the baseline gas* model[4]. = 3,500 Btu/hr/ft^2 * *Includes both natual gas and propane*
$IdleRateGas_{ESTAR}$	=	*Normalized* Idle Energy Rate of the ENERGY STAR certified gas* model[5] = 2,650 Btu/hr/ft^2 * *Includes both natual gas and propane*
LB	=	Pounds of food cooked per day. = 100 lbs / day[2]

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLGRIDL	Energy Star Griddle

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLGRIDL	1.00	1.00

Lifetimes

The expected measure life is assumed to be 12 years[9].

Measure Cost

Incremental costs are assumed to be as follows:

Fuel Type	Number of Heated Sides	Incremental Cost
Gas *	Single	$449[10]
Electric	Single	$662[10]
Dual Fuel *	Double	$795[11]
Electric	Double	$877[12]

* *Includes both natual gas and propane*

O&M Cost Adjustments

No operation and maintenance cost adjustments are applicable to this measure.

Reference Table

The following table shows the algorithm outcomes[13] and corresponding ItemCode:

Energy Source	# of sides	ΔkW	ΔkWh	ΔMMBtu	ItemCode
Electric	Single-Sided	0.4360	1,632	*n/a*	CI-KTN-GRID-ELSN
Natural Gas	Single-Sided	*n/a*	*n/a*	11.22	CI-KTN-GRID-NGSN
Propane	Single-Sided	*n/a*	*n/a*	11.22	CI-KTN-GRID-PPSN
Electric / Natural Gas	Double-Sided	0.4391	1,644	5.61	CI-KTN-GRID-NGDB
Electric / Propane	Double-Sided	0.4391	1,644	5.61	CI-KTN-GRID-PPDB
Electric	Double-Sided	0.6075	2,274	*n/a*	CI-KTN-GRID-ELDB

Footnotes

[1] Assumes operation 6 out of 7 days per week. 6 days/week x 52 week/year = 312 days/year.

[2] Assumption consistent with the ENERY STAR Certified Commercial Kitchen Equipment Savings Calculator (version updated October 2016). *Please see Referenced Document.*

[3] As per DOE workpaper *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances (pg.166)* these models have a "second heating plate that is lowered on top of the food and used to simultaneously cook both sides." Given the equipment Energy Source breakdown, it is therefore reasonable to assume the savings are split 50% gas versus electric. *Please see Referenced Document.*

[4] Assumption consistent with the ENERY STAR Certified Commercial Kitchen Equipment Savings Calculator (version updated October 2016). Baseline equipment specifications source Food Service Technology Center (FSTC) research on available models, 2011. *Please see Referenced Document.*

[5] As specified in ENERGY STAR® Program Requirements Product Specification for Commercial Griddles, Eligibility Criteria Version 1.2. *See Referenced Document.*

[6] California Public Utilities Commission. Work Paper SWFS004-01. FOOD SERVICE, Commercial Griddle – Electric & Gas. *Please see Referenced Document. Excel File Name =* MeasureDataSpec, *Sheet Name =* Measure Specific Constants, *Cell* = C18, "Production Capacity (lbs/hr)". 2018.

[7] California Public Utilities Commission. Work Paper SWFS004-01. FOOD SERVICE, Commercial Griddle – Electric & Gas. *Please see Referenced Document. Excel File Name =* MeasureDataSpec, *Sheet Name =* Measure Specific Constants, *Cell* = C17, "Heavy Load Cooking Energy Efficiency, Energy Efficient Model (%)". 2018.

[8] California Public Utilities Commission. Work Paper SWFS004-01. FOOD SERVICE, Commercial Griddle – Electric & Gas. *Please see Referenced Document. Excel File Name =* MeasureDataSpec, *Sheet Name =* Measure Specific Constants, *Cell* = C15, "Normalized Idle Energy Rate, Energy Efficient Model (watts per ft^2). 2018.

[9] California Public Utilities Commission. Database for Energy Efficient Resources. Effective Useful Life Table (2014). *Please see Referenced Document. Excel File Name =* MeasureDataSpec, *Sheet Name =* READI_EUL, *Cells =* D48 & D53.

[10] California Public Utilities Commission. Work Paper SWFS004-01. FOOD SERVICE, Commercial Griddle – Electric & Gas. *Please see Referenced Document. Excel File Name =* MeasureDataSpec, *Sheet Name =* Measure Support Table, *Cell* = AK "Incremental Cost". 2018.

[11] *Derived from* California Energy Wise, Gas Double-Sided Griddle Energy Savings Calculator. California Public Utilities Commission. Accessed June 2020: https://caenergywise.com/calculators/natural-gas-double-griddles/#calc

[12] *Derived from* California Energy Wise, Electric Double-Sided Griddle Energy Savings Calculator. California Public Utilities Commission. Accessed June 2020: https://caenergywise.com/calculators/electric-double-griddles/#calc

[13] *Please see Referenced .xcl Document:* ENERGY STAR Commercial Griddle Analysis_2020 *for full calculations.*

ENERGY STAR Hot Food Holding Cabinet

Measure Number: CI-KTN-HFHC a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

This is version one of the TRM characterization.

Referenced Documents

Linked below are the ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets, Eligibility Criteria Version 2.0, which defines the efficient and eligible equipment and the Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment, from which impact algorithms and assumptions are referenced.

- EPA_Commercial Kitchen Equipment Calculator_Oct 2016
- ENERGY STAR CKE Calculator_Oct 2016
- Commercial_HFHC_Program_Requirements_2.0
- commercial_kitchen_equipment_calculator_HFHC

Description

A commercial hot food holding cabinets (HFHC) is a heated, fully enclosed compartment with one or more solid or transparent doors designed to maintain the temperature of hot food that has been cooked using a separate appliance. HFHC's are used to extend the amount of time foodservice operators can hold food prior to serving. Preparing food in advance can free up cooking resources to perform other tasks, allowing hot food holding equipment to increase speed of service, particularly during peak service hours of the day.

This measure is a hot food holding cabinet that has achieved ENERGY STAR certification by meeting Version 2.0 eligibility criteria.

NOTE: there are very few (if any) non-electric HFHC offerings within the market. ENERGY STAR certified units currently consist of electric only equipment.

ENERGY STAR certified hot food holding cabinets often incorporate better insulation which reduces heat loss, offer better temperature uniformity within the cabinet from top to bottom, and keeps the external cabinet cooler. In addition, many certified holding cabinets may include energy saving devices such as magnetic door gaskets, auto-door closures, or Dutch doors.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Mid stream

This characterization was developed for measure implementation by way of a midstream program with commercial kitchen equipment dealers.

Units rebated through the program will map to one of the nine products summarized in the Reference Tables section below.

Baseline Efficiencies

The baseline condition is a hot food holding cabinet that is not ENERGY STAR certified.

Efficient Equipment

The efficient condition is a hot food holding cabinet that has achieved ENERGY STAR certification by meeting Version 2.0 eligibility criteria.[1]

Algorithms

Electric Demand Savings

ΔkW	$= (Idle_{Base} - Idle_{EStar}) / 1000$

Symbol Table

Water Savings

No water savings are expected.

Electric Energy Savings

ΔkWh	$= (IdleRate_{Base} - IdleRate_{EStar}) / 1000 \times Hours \times Days$
$IdleRate_{Base}$	$= 40 \times Volume$
$IdleRate_{EStar}$	$= (A \times Volume) + B$

Symbol Table

Fossil Fuel Savings

No fossil fuel impacts are characterized for this measure.

Where:

ΔkW = Gross electric demand savings (kW).

ΔkWh = Gross annual electric energy savings (kWh).

1000 = Conversion factor, from W to kW.

40 = Volumetric baseline idle energy rate, (Watts/ft^3)[2]

A = Volumetric idle energy rate of ENERGY STAR certified unit, (Watts/ft^3), dependent on Volume category.[3]

=

Product Interior Volume (Cubic Feet)	A
0 < Volume < 13	21.5
13 ≤ Volume < 28	2.0
28 ≤ Volume	3.8

B = Constant, (Watts), dependent on Volume category.[3]

=

Product Interior Volume (Cubic Feet)	B
0 < Volume < 13	0
13 ≤ Volume < 28	254.0
28 ≤ Volume	203.5

Days = Annual days the HFHC is in operation

= 312 days/year[4]

Hours = Operating hours per day

= 15 hours/day[5]

$IdleRate_{Base}$	=	Idle energy rate the baseline unit. Idle energy rate is the rate of appliance energy consumption while it is maintaining or holding at the control set point. Units are Watts.
$IdleRate_{EStar}$	=	Idle energy rate of ENERGY STAR certified unit. Idle energy rate is the rate of appliance energy consumption while it is maintaining or holding at the control set point. Units are Watts.
Volume	=	Interior volume of the commercial hot food holding cabinet, in cubic feet, as measured by ENERGY STAR Version 2.0 qualification criteria.

ENERGY STAR specifications recognize three distinct size classes for establishing maximum idle energy rates:

Product Interior Volume (Cubic Feet)
0 < V < 13
13 ≤ V < 28
28 ≤ V

Note: V = Interior volume in cubic feet (ft^3).

For the purpose of claiming savings, the ENERGY STAR categories are broken out into size categories (two for the first and second class and five for the third class), and a deemed value is assigned per the following table. This approach strikes a balance with granularity in savings and implementability.

Size Class	Size Category	Deemed Size* (cubic feet (ft^3))
0 < V < 13	0 < V < 6.5	3.25
0 < V < 13	6.5 ≤ V < 13	9.75
13 ≤ V < 28	13 ≤ V < 20.5	16.75
13 ≤ V < 28	20.5 ≤ V < 28	24.25
28 ≤ V	28 ≤ V < 48	38
28 ≤ V	48 ≤ V < 68	58
28 ≤ V	68 ≤ V < 88	78
28 ≤ V	88 ≤ V < 108	98
28 ≤ V	108 ≤ V	111

* Midpoints of size categories are used, with the exception of 108 ≤ V using 111 which is the size of the largest ENERGY STAR qualified unit.

Mid-Life Savings Adjustment

No mid-life savings adjustments are applicable to this measure.

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLHFOOD	Energy Star Hot Food Holding Cabinet

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLHFOOD	1.00	1.00

Lifetimes

Equipment lifetime is 12 years.[6]

Measure Cost

The incremental cost for an ENERGY STAR certified unit is $902.[7]

Operation and Maintenance Cost Adjustments

No operation and maintenance cost adjustments are applicable to this measure.

Reference Tables

The following table shows the algorithm outcomes and correcsponding ItemCode:

Size Category	Deemed Volume (ft^3)	$Idle_{Base}$ (W)	$Idle_{EStar}$ (W)	ΔkWh	ΔkW	ItemCode
0 < V < 6.5	3.25	130.000	69.875	281.4	0.06013	CI-KTN-HFHC-003
6.5 ≤ V < 13	9.75	390.000	209.625	844.2	0.18038	CI-KTN-HFHC-009
13 ≤ V < 20.5	16.75	670.000	287.500	1790.1	0.38250	CI-KTN-HFHC-016
20.5 ≤ V < 28	24.25	970.000	302.500	3123.9	0.66750	CI-KTN-HFHC-024
28 ≤ V < 48	38.00	1520.000	347.900	5485.4	1.17210	CI-KTN-HFHC-038
48 ≤ V < 68	58.00	2320.000	423.900	8873.7	1.89610	CI-KTN-HFHC-058
68 ≤ V < 88	78.00	3120.000	499.900	12262.1	2.62010	CI-KTN-HFHC-078
88 ≤ V < 108	98.00	3920.000	575.900	15650.4	3.34410	CI-KTN-HFHC-098
108 ≤ V	111.00	4440.000	625.300	17852.8	3.81470	CI-KTN-HFHC-111

Note: V = Interior volume in cubic feet (ft^3).

Footnotes

[1] See complete qualification criteria in reference file ***Commercial_HFHC_Program_Requirements_2.0***. See Referenced Document Commercial_HFHC_Program_Requirements_2.0.

[2] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references **Food Service Technology Center (FSTC) research on available models, 2011**. See Referenced Document commercial_kitchen_equipment_calculator_HFHC.

[3] As specified in ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets, Eligibility Criteria Version 2.0. See Referenced Document Commercial_HFHC_Program_Requirements_2.0.

[4] Assumes operation 6 out of 7 days per week. 6 days/week x 52 week/year = 312 days/year.

[5] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references ***FSTC research on average use, 2011***. See Referenced Document commercial_kitchen_equipment_calculator_HFHC.

[6] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references **FSTC research on available models, 2009**. See Referenced Document commercial_kitchen_equipment_calculator_HFHC.

[7] Assumption consistent with the Savings Calculator for ENERY STAR Certified Commercial Kitchen Equipment (version updated 2016), which references ***Difference between a similar ENERGY STAR and non-qualifying model, EPA research using AutoQuotes, 2012***. See Referenced

Document commercial_kitchen_equipment_calculator_HFHC.

Rack Oven

Measure Number: CI-KTN-ROVN a
Portfolio: EVT TRM Portfolio 2020-06
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Kitchen Equipment

Update Summary

New Measure

Referenced Documents

- DOE - Energy Savings Potential RDD Opportunities for Comm Bldg Appliances_2015
- DEER EUL Table_2014-02-05
- PGECOFST109 R6 Commercial Rack Oven - Gas_2016
- FSTC Oven Technology Assessment Section 7: Ovens
- Rack Oven - Gas_Analysis 2020

Description

This measure applies to gas fired high efficiency Rack Ovens (Double) installed in a commercial kitchen.

Rack Ovens are used for high-volume institutional operations, consist of roll-in racks which hold between 10 to 15 pans and utilize "heat exchangers of various designs [and] a power blower which circulates heat evenly throughout the cooking cavity" [1]. Some models have options such as a rotating mechanism to spin the rack or a steam injection system to mimic a combination oven[2]. They are capable of producing thousands of identical or many divesre items.[1]

There is no current federal baseline, so the measure was developed using ASTM Standard Test Method for the Performance of Commercial Rack Ovens (F2093). While ENERGY STAR standards do exist, the number of certified products on the current market is extremely limited.

Program Type

Calculation Type: Market Opportunity - TOS

Program Delivery / Implementation Type: Midstream

Baseline Efficiencies

The baseline equipment is a new gas rack oven – double oven with a Cooking-Energy Efficency of 30%[3].

Efficient Equipment

The efficient equipment is a new gas rack oven – double oven with a Cooking-Energy Efficiency ≥ 50% tested utilizing the ASTM Standard Test Method for the Performance of Commercial Rack Ovens (F2093)[4]. The Idle Energy Rate should not exceed 35,000 Btu/hr.

Due to an extremely limited market, this measure was not developed using ENERGY STAR specifications.

Algorithms

Electric Demand Savings
N/A

Electric Energy Savings
N/A

Fossil Fuel Savings
All assumptions, except where noted, are based on Work Paper PGECOFST109 R6 "Commercial Rack Oven - Gas".
Using assumptions provided, the deemed savings for this measure is **180.65 MMBtu**. (ItemCode = CI-KTN-ROVN-NG or CI-KTN-ROVN-LP depending on fuel type).

ΔMMBtu	= (ΔPreheatDailyBtu + ΔIdleDailyBtu + ΔCookingDailyBtu) x Days / 1,000,000
ΔPreheatDailyBtu	= $(Preheat_{BASE} \times N_P) - (Preheat_{EE} \times N_P)$
ΔIdleDailyBtu	= $(IdleRate_{BASE} \times (Hours - (LB_{FOOD} / Capacity_{BASE}) - (N_P \times PreheatTime/60))) - (IdleRate_{EE} \times (Hours - (LB_{FOOD} / Capacity_{EE}) - (N_P \times PreheatTime/60)))$
ΔCookingDailyBtu	= $(LB_{FOOD} \times E_{FOOD}/Eff_{BASE}) - (LB_{FOOD} \times E_{FOOD}/Eff_{EE})$

Where:

ΔCookingDailyBtu	=	Gross Daily Gas Energy Savings, while *in Cooking mode* (Btu).
ΔIdleDailyBtu	=	Gross Daily Gas Energy Savings, while *in Idle mode* (Btu).
ΔMMBtu	=	Gross Annual Gas Energy Savings for an efficient rack oven (MMBtu)
ΔPreheatDailyBtu	=	Gross Daily Gas Energy Savings, while *in Preheat mode* (Btu).
1,000,000	=	Converts Btu to MMBtu
60	=	Converts minutes to hours
$Capacity_{BASE}$	=	Production capacity of baseline gas rack oven. = 250 lb / hr
$Capacity_{EE}$	=	Production capacity of efficient gas rack oven. = 280 lb / hr
Days	=	Annual days the rack oven is in operation. = 312 days[5]
E_{FOOD}	=	ASTM Energy to Food, measured in Btu per lb of energy absorbed by food product during cooking. = 235 Btu / lb
Eff_{BASE}	=	Heavy Load Cooking Energy Efficiency of baseline rack oven. = 30%
Eff_{EE}	=	Heavy Load Cooking Energy Efficiency of efficient rack oven. = 50%
Hours	=	Average Daily Operating Hours = 12 hrs / day
$IdleRate_{BASE}$	=	Idle Energy Rate of baseline gas rack oven. = 65,000 Btu / hr
$IdleRate_{EE}$	=	Idle Energy Rate of efficient gas rack oven. = 35,000 Btu / hr

LB_{FOOD}	=	Estimated Pounds of Food Cooked per Day = 1,200 lb /d
N_P	=	Number of Preheats per day = 1 / day
$Preheat_{BASE}$	=	Preheat Energy of baseline gas rack oven. = 100,000 Btu
$Preheat_{EE}$	=	Preheat Energy of baseline gas rack oven. = 85,000 Btu
PreheatTime	=	Estimated time of each Preheat = 20 minutes

Load Shapes

90b Restaurant Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
90	Restaurant Indoor Lighting	Active	40.7%	25.7%	20.2%	13.4%	63.0%	77.0%

Net Savings Factors

Measures

CKLORACK	Rack Oven

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	CKLORACK	1.00	1.00

Lifetimes

Equipment lifetime is 12 years[6].

Measure Cost

Incremental costs for an Energy Efficient model are assumed to be $4,128 per oven.[7]

Reference Table

The following table shows the algorithm outcomes and corresponding ItemCode:

Energy Source	Size Class	ΔPreheatDailyBtu	ΔIdleDailyBtu	ΔCookingDailyBtu	ΔkW	ΔkWh	ΔMMBtu	ItemCode
Natural Gas	Double Oven	15,000	188,000	376,000	N/A	N/A	180.65	CI-KTN-ROVN-NG
Propane	Double Oven	15,000	188,000	376,000	N/A	N/A	180.65	CI-KTN-ROVN-LP

Footnotes

[1] FSTC Oven Technology Assessment, Section 7: Ovens, pg 7. *Please see Referenced Documents.*

[2] US Department of Energy EERE Report "Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances (2015 Update)", June 2016. App A, pg 169.

[3] Per the Pacific Gas & Electric Company Work Paper PGECOFST109 R6 "Commercial Rack Oven - Gas", April 2016. pg.2. "In the absence of mandatory regulations for testing commercial rack ovens, there is little incentive on the part of equipment manufacturers to have their baseline equipment tested. Therefore, the ASTM performance parameters for baseline equipment were drawn from a sample of economy grade equipment tested by the Food Service Technology Center"

[4] Based on Pacific Gas & Electric Company Work Paper PGECOFST109 R6 "Commercial Rack Oven - Gas", April 2016. Table 4 "Measure Test Results for Energy Efficinet Commercial Rack Ovens", pg. 2. *Please see Referenced Documents.*

[5] Assumes operation 6 out of 7 days per week. 6 days/week x 52 week/year = 312 days/year.

[6] California Public Utilities Commission. Database for Energy Efficient Resources. Effective Useful Life Table (2014). *Please see Referenced Document.*

[7] Based on Pacific Gas & Electric Company Work Paper PGECOFST109 R6 "Commercial Rack Oven - Gas", April 2016. App A Table "Equipment Incremental Cost Data for Energy Efficient Rack Ovens", pg. 11. *Please see Referenced Documents.*

ENERGY STAR Dishwasher

Measure Number: VI-H-1 h
Portfolio: EVT TRM Portfolio 2017-07
Status: Active
Effective Date: 2018/1/1
End Date: 2022/12/31
Program: Residential New Construction
End Use: Kitchen Equipment

Update Summary

The ENERGY STAR Dishwasher measure has been updated according to the 3-year reliability review schedule.

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- ACEEE_Better Appliances_May 2013
- EVT_ENERGY STAR Dishwasher_Analysis_June2017_v4

Description

A standard or compact dishwasher meeting the ENERGY STAR/CEE Tier 1 efficiency specifications is installed in place of a model meeting the federal standard..

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / (Ncycles × Hours/Cycle)

Symbol Table

Electric Energy Savings

ΔkWh	= ((kWh_Base - kWh_EE) × %Electric_DHW) + ((kWh_Base - kWh_EE) × %Dishwasher × (%Fuel_DHW, oil + %Fuel_DHW, propane + %Fuel_DHW, natural gas))

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= ((kWh_Base - kWh_EE) × %DHW × 3,412 × ηElectric_DHW / ηFuel_DHW) / 1,000,000

Symbol Table

Water Savings

ΔCCF	= (Gallons/Cycle_Base - Gallons/Cycle_EE) × Ncycles / 748

Where:

%DHW = Percentage of total energy consumption used for water heating (deemed, dependent on dishwasher type)

Dishwasher Type	%DHW[3]
Standard	45%
Compact	54%

%Dishwasher = Percentage of total energy consumption used for dishwasher operation (deemed, dependent on dishwasher type)

Dishwasher Type	%Dishwasher[3]
Standard	55%
Compact	46%

%Electric_DHW = Percentage of DHW savings assumed to be electric (deemed)

= 24%[4]

%Fuel_DHW = Percentage of DHW savings assumed to be non electric (deemed, dependent on DHW fuel type)

DHW Fuel Type	%Fuel_DHW[4]
Oil	10%
Natural Gas	14%
Propane	52%

ΔCCF = Customer water savings in hundreds of cubic feet for the measure (output)

See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure (output)

See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure (output)

See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure (output)

See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater (deemed)

= 0.98[7]

ηFuel_DHW = Recovery efficiency of fuel water heater (deemed, dependent on DHW fuel type)

DHW Fuel Type	ηFuel_DHW[8]
Oil	0.80
Natural Gas	0.74
Propane	0.84

1,000,000 = Conversion factor from Btu to MMBtu (constant)

3,412 = Conversion factor from Btu to kWh (constant)

748 = Conversion factor from gallons to CCF (constant)

Gallons/Cycle_Base = Amount of water (gallons/cycle) used by baseline dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	Gallons/Cycle_Base[5]
Standard	5.0
Compact	3.5

Gallons/Cycle_EE = Amount of water (gallons/cycle) used by efficient dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	Gallons/Cycle_EE[6]
Standard	3.15
Compact	2.63

Hours/Cycle	=	Dishwasher runtime (hours) per cycle = 2.1 hours[1]
kWh_Base	=	Annual energy consumption of baseline dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	kWh_Base[5]
Standard	307
Compact	222

kWh_EE	=	Annual energy consumption of efficient dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	kWh_EE[6]
Standard	259.0
Compact	181.6

Ncycles	=	Number of dishwasher cycles per year (deemed) = 175 cycles/year[2]

Baseline Efficiencies

The baseline reflects the minimum federal efficiency standards for dishwashers effective May 30, 2013, as presented in the table below.

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard	307	5.0
Compact	222	3.5

High Efficiency

The efficient equipment is defined as a dishwasher meeting the efficiency specifications of ENERGY STAR version 6.0, effective January 29, 2016, which are indentical to CEE Tier 1 specifications.

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard (≥ 8 place settings + six serving pieces)	270	3.5
Compact (< 8 place settings + six serving pieces)	203	3.1

Operating Hours

Load Shapes

8a Residential DHW conserve

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7%	29.1%	14.3%	7.9%	40.1%	20.3%

Net Savings Factors

Measures

CKLSEDRP	Energy Star dishwasher, standard
CKLCEDRP	Energy Star Dishwasher Compact

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	CKLSEDRP	0.90	1.10
RNC VESH	6038VESH	CKLCEDRP	0.90	1.10

Persistence

The persistence factor is assumed to be one.

Lifetimes

11 years[9]

Analysis period is the same as the lifetime.

Measure Cost

Dishwasher Type	Baseline Cost	ENERGY STAR Cost	Incremental Cost[10]
Standard	$255.63	$331.30	$75.67
Compact	$290.13	$308.62	$18.49

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

Fossil fuel savings are presented for each dishwasher type in the Reference Table section below.

Reference Tables

Savings for each dishwasher type are presented in the table below.[11]

Savings Type	Dishwasher Type	
	Standard	Compact
ΔkWh	31.7	23.6
ΔkW	0.08549	0.06373
ΔMMBtu (oil)	0.0089	0.0092
ΔMMBtu (natural gas)	0.0135	0.0139
ΔMMBtu (propane)	0.0445	0.0457

ΔCCF (water savings)	0.43	0.20

Footnotes

[1] Average cycle length for all dishwasher models reviewed by Consumer Reports in 2012, from ACEE and ASAP, "Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved," May 2013, Table 9, page 34.

[2] Dishwasher cycles per year based on 2015 Residential Energy Consumption (RECS) data for New England provided by the U.S. Energy Information Administration. See file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx for calculation details.

[3] %DHW and %Dishwasher based on data from U.S. DOE, Final Rule Life-Cycle Cost (LCC) Spreadsheet. See "%DHW" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx.

[4] Based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Federal appliance standards effective May 30, 2013

[6] Average of products available on ENERGY STAR qualified products list, June 2017. See "Per Unit Savings" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx.

[7] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

[8] ηFuel_DHW based on a weighted average of DHW system efficiencies in new homes in Vermont, from "Vermont Residential New Construction Baseline Study Analysis of On-Site Reports," February 13, 2013, Table 7-4, pages 97-99. See "Energy Savings" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx.

[9] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[10] Costs are based on data from U.S. DOE, Final Rule Life-Cycle Cost (LCC) Spreadsheet. See "Costs" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx for cost calculation details.

[11] See file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx for savings calculation details.

Multi Family Common Area Clothes Dryer

Measure Number: CI-LAU-CACD a
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Multifamily
End Use: Laundry

Update Summary

New multifamily clothes dryer measure. Almost all common area laundry in the target multifamily market use residential sized units, therefore this common area meausre is based on the residential measure but with a lowered number of cycles per unit assumption,

Referenced Documents

- 2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses
- efficiency-common-laundry-areas-sahf-20170327
- MF Clothes Dryer Analysis

Description

Install in a multi family common area a residential-grade clothes dryer meeting minimum qualifying efficiency standards for ENERGY STAR (standard sized or compact), ENERGY STAR Most Efficient Hybrid Heat Pumps (all standard sized) and ENERGY STAR Most Efficient Full Heat Pumps (all compact units), based on Combined Energy Factor (CEF), as described below under High Efficiency. This is characterized as a market opportunity and an early replacement measure.

The CEF measures energy consumption of the total dryer cycle (standby usage, dryer heating and operation) in units of weight (lbs) of clothing dried per kWh of electricity; the higher the number, the greater the efficiency. In the case of gas dryers, the CEF combines both the gas and electric usage into a single CEF metric also measured in units of weight of clothing dried per kWh of electricity.

Program Type

Calculation Type: Market Opportunity and Early Replacement

Program Delivery / Implementation Type: Downstream

Baseline Efficiencies

Market Opportunity:

The baseline combined energy factor (CEF) was derived in the ENERGY STAR Version 1.0 analysis by multiplying 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements. This gives 3.11 CEF for standard electric dryers, 3.01 for compact 120V dryers, 2.73 for vented 240V dryers and 2.13 for compact ventless dryers.

Early Replacement:

The baseline in this case is the efficiency of the existing unit for its assumed remaining life (4 years) and the new baseline as defined above for the remainder of the measure (remaining 8 years). The Federal baseline for clothes dryers prior to 2015 had been in place since 1994. The standard was 3.01 EF for electric units. Comparing new units Combined Energy Factor (which include accounting for standby loads in addition to active drying energy) with older units Energy Factor (which only accounts for active drying energy) is challenging and complicated further by significant changes in testing procedures over the years. However, there hasn't been significant change in actual clothes dryer performance over the past decades and using these EF without any adjustment is consistent with this, only representing approximately 3% lower efficiency than the new baseline, and is used as an estimate of existing unit efficiency.

Applying the same ratio of old standard to new is applied to the new standard for compact units to estimate an existing baseline of 2.91CEF for compact 120V dryers, 2.64 for vented 240V dryers and 2.06 for compact ventless dryers. .

Efficient Equipment

High efficiency is defined as any model meeting or exceeding ENERGY STAR or ENERGY STAR Most Efficient criteria, as defined in the following table:

	Combined Energy Factor (CEF) Lbs / kWh	
	ENERGY STAR	ENERGY STAR Most Efficient
Standard Sized	>= 3.93	>= 4.3
Compact 120V	>= 3.8	>= 4.3
Compact 240V Ventled	>= 3.45	>= 4.3
Compact 240V Ventless	>=2.68	>= 3.7

Energy savings estimates are based on the resulting product from multiplying the average CEF of units purchased through the Efficiency Vermont program during 2017 and 2018. An additional waste heat calculation has been incorporated in to the final savings determination. This accounts for the unit's waste heat either being predominately vented to outside or remaining in the home and reducing the heating demands (notably in ventless hybrid and full heat pump models).

Algorithms

Electric Demand Savings

Energy and Demand savings per unit served by the clothes dryer are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer.

Savings per MF unit are consistent with assumptions in the Efficient Product measure (see measure for write up of savings methodology), however number of of cycles per year per unit is reduced from 265 (assumed for in-unit multi family) to 112 (common area multi family) as presented below.

Savings per MF unit are then multiplied by the #units served / #washers. Note only units without in-unit clothes washers should be counted.

ΔkW	= ΔkWPer MF unit × NumUnits / NumDryers
ΔkWPer MF unit	= See table below of savings based on Efficient Products measure with lowered N_{Cycles} assumption.

Symbol Table

Electric Energy Savings

ΔkWh	= ΔkWhPer MF Unit × NumUnits / NumDryers
ΔkWhPer MF Unit	= See table below of savings based on Efficient Products measure with lowered NCycles assumption

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= ΔMMBtu Per MF Unit × NumUnits / NumDryers
ΔMMBtu Per MF Unit	= See table below of savings based on Efficient Products measure with lowered NCycles assumption

Where:

ΔkW	=	Gross customer connected load kW savings for the measure
ΔkWh	=	Total gross customer annual kWh savings for the measure
ΔkWhPer MF Unit	=	Gross customer annual kWh savings per MF unit
ΔkWPer MF unit	=	Gross customer connected load kW savings per MF unit
ΔMMBtu Per MF Unit	=	Gross fuel savings per MF unit
ΔMMBtu	=	Total gross fuel savings for the measure
NCycles	=	Number of Cycles per year per unit = 112[1]
NumDryers	=	Total number of clothes dryers in central laundry facility
NumUnits	=	Number of residential units (apartments) served by the central laundry facility

Mid Life Savings Adjustment

The follow mid life savings adjustments are applied to the annual savings for early replacement measures after 4 years:

Efficiency Level	Electric Adjustment	Fossil Adjustment
ENERGY STAR	86%	94%
ENERGY STAR Most Efficient Hybrid	92%	100%
ENERGY STAR Most Efficient Full Heat Pump	96%	93%

Load Shapes

134a MF Common Area Laundry

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
134	MF Common Area Laundry	Active	42.0%	28.8%	16.9%	12.3%	11.6%	8.7%

Net Savings Factors

Measures

CKLESDRY	Energy Star Clothes Dryer
CKLESETA	Energy Star Most Efficient Clothes Dryer
CKLERESD	Early Replacement ENERGY STAR Clothes Dryer
CKLERETD	Energy Star Most Efficient Clothes Dryer, Early Replacement

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES
6020CUST [is base track]	6020CUST

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	CKLESDRY	1.00	1.00
LIMF NC	6018LINC	CKLESETA	1.00	1.00
MF Mkt NC	6019MFNC	CKLESDRY	0.95	1.10
MF Mkt NC	6019MFNC	CKLESETA	0.95	1.10
6017PRES	6017PRES	CKLESDRY	1.00	1.00
6017PRES	6017PRES	CKLESETA	1.00	1.00
6017CUST	6017CUST	CKLESDRY	1.00	1.00
6017CUST	6017CUST	CKLESETA	1.00	1.00
6020PRES	6020PRES	CKLESDRY	0.90	1.00
6020PRES	6020PRES	CKLESETA	0.90	1.00
6020CUST	6020CUST	CKLESDRY	0.90	1.00
6020CUST	6020CUST	CKLESETA	0.90	1.00
LIMF NC	6018LINC	CKLERESD	1.00	1.00
MF Mkt NC	6019MFNC	CKLERESD	0.95	1.00
6017PRES	6017PRES	CKLERESD	1.00	1.00
6017CUST	6017CUST	CKLERESD	1.00	1.00
6020PRES	6020PRES	CKLERESD	0.90	1.00
6020CUST	6020CUST	CKLERESD	0.90	1.00
LIMF NC	6018LINC	CKLERETD	1.00	1.00
MF Mkt NC	6019MFNC	CKLERETD	0.95	1.00
6017PRES	6017PRES	CKLERETD	1.00	1.00
6017CUST	6017CUST	CKLERETD	1.00	1.00
6020PRES	6020PRES	CKLERETD	0.90	1.00
6020CUST	6020CUST	CKLERETD	0.90	1.00

Lifetimes

12 years[2]

Analysis period is the same as the lifetime.

For early replacement the existing unit is assumed to have a remaining life of 4 years (1/3 of the measure life).

Measure Cost

The incremental cost and full install cost for this measure is provided in the table below[3]:

Efficiency Level	Market Opportunity Incremental Cost	Early Replacement Full Install Cost
ENERGY STAR	$61	$528
ENERGY STAR Most Efficient	$412	$879

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 4 years had the existing unit not been replaced is assumed to be $467.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Prescriptive Savings Tables

Deemed savings for this measure are provided below. For ENERGY STAR it is the weighted (by product in program) average of Standard ENERGY STAR units and Compact 240V Ventless ENERGY STAR. ENERGY STAR Most Efficient Hybrid Heat Pump are all Standard sized. ENERGY STAR Most Efficient Full Heat Pump is the weighted (by product in program) average of Compact 120V Full Heat Pump and Compact 240V Ventless Full Heat Pump.

	Item Code	ΔkWh per MF unit	ΔkW per MF unit	ΔMMBtu per MF unit			
				NG	LP	Oil	Wood
ENERGY STAR	MFCCKLDRYES	68	0.6043	-0.001	-0.002	-0.004	-0.004
ENERGY STAR Most Efficient Hybrid	MFCCKLDRYETA2	128	1.1399	0.07	0.14	0.23	0.27
ENERGY STAR Most Efficient Full Heat Pump	MFCCKLDRYETA3	205	1.8341	-0.01	-0.00	-0.01	-0.07

For Early Replacment measures, the first four years will assume the following savings before applying the midlife adjustment provided above:

	Item Code	ΔkWh per MF unit	ΔkW per MF unit	ΔMMBtu per MF unit			
				NG	LP	Oil	Wood
ENERGY STAR	MFCCKLDERES	79	0.7010	-0.001	-0.002	-0.004	-0.004
ENERGY STAR Most Efficient Hybrid	MFCCKLDERBT	139	1.2369	0.07	0.14	0.23	0.27
ENERGY STAR Most Efficient Full Heat Pump	MFCCKLDERHT	215	1.9158	0.00	0.00	0.01	0.06

Footnotes

[1] A 2001 National Research Study: "A National Study of Water & Energy Consumption in Multifamily Housing; In-Apartment Washers vs Common Area Laundry rooms", found that residents with in-unit washers do 5.22 loads per week on average, while residents using common area laundry do 2.16 loads per week.

[2] Based on average lifetime in DOE Buildings Data Book http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.15

[3] See "MF Clothes Dryer Analysis.xlsx", "Incremental Cost" tab. Based on DOE Life-Cycle Cost and Payback Period analysis Table 8.3.1.

Multi Family Common Area Clothes Washer

Measure Number:	CI-LAU-CACW a
Portfolio:	EVT TRM Portfolio 2020-06
Status:	Active
Effective Date:	2020/1/1
End Date:	[None]
Program:	Multifamily
End Use:	Laundry

Update Summary

New multifamily clothes washer measure - either residential or commercial grade.

Created new loadshape for MF Common Area Laundry.

Referenced Documents

- efficiency-common-laundry-areas-sahf-20170327
- DOE Life-Cycle Cost and Payback Period Tool
- MF Common Area Commercial Clothes Washer_ 2020

Description

Install in a multi family common area a residential or commercial-grade clothes washer meeting minimum qualifying efficiency standards of ENERGY STAR/CEE Tier 1 or CEE Tier 2. Efficiency levels are defined below. This is characterized as a market opportunity and an early replacement measure.

Program Type

Calculation Type: Market Opportunity and Early Replacement

Program Delivery / Implementation Type: Downstream

Baseline Efficiencies

Market Opportunity:

Baseline efficiency is a residential or commercial-grade clothes washer meeting the appropriate federal standard.

The baseline efficiency is determined according to the Integrated Modified Energy Factor (IMEF) for residential units and MEF_{J2} for Commercial units. These ratings take into account the machine electrical energy, the hot water energy consumption required per clothes washer cycle, and the energy required for removal of the remaining moisture by a clothes dryer (plus for residential units only the combined low-power mode energy consumption).

The federal standard baseline for Residential sized units as of January 2018 is >=1.84 IMEF and <=4.7 IWF for front loading units and >=1.57 IMEF and <=6.5 IWF for top loading units.

The federal standard baseline for Commercial grade units as of January 2018 is >=2.0 MEF and <=4.1 IWF for front loading units and >=1.35 MEF and <=8.8 IWF for top loading units.

Early Replacement Baseline:

The baseline in this case is the efficiency of the existing unit for its assumed remaining life (3 years) and the new baseline as defined above for the remainder of the measure (remaining 11 years).

For Residential units, the eligibility for this measure is limited to pre-2004 non-Energy Star units. The Federal baseline for clothes washers prior to 2004 was 0.817 MEF, and the average value of units tested in a 2001 DOE market assessment was 1.164MEF. Converting MEF to IMEF using an ENERGY STAR conversion tool copied in to the reference calculation spreadsheet "MF Common Area Commercial Clothes Washer 2020.xls", provides the assumption for existing units of 0.91 IMEF for front loading machines and 0.74 IMEF for top-loading. Similarly converting 12.87 WF to IWF gives 13.3 IWF for front loading and 13.2 IWF for top loading units.

For Commercial units, the eligibility for this measure is limited to pre-2013 non-Energy Star units. The Federal baseline for clothes washers prior to 2013 was 1.26 MEF. The same ENERGY STAR conversion tool is used to estimate converting MEF to MEF_{J2}, providing the assumption for existing units of 1 MEF for front loading machines and 0.84 MEF for top-loading. Similarly converting 9.5 WF to IWF gives 9.8 IWF for front loading and 9.9 IWF for top loading units.

High Efficiency

For Residential grade units, high efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or CEE Advanced Tier as defined in the following table:

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR	>= 2.76	>= 2.06	<= 3.2	<= 4.3
CEE TIER 2	>= 2.92	n/a	<= 3.2	n/a

For Commercial grade units, high efficiency is defined as any model meeting or exceeding ENERGY STAR criteria - >=2.2 MEF_{J2} and <=4.0 IWF.

Algorithms

Electric Demand Savings

Energy and Demand savings per unit served by the clothes washer are presented in the reference tables below, and are dependent on the fuel type of the DHW system and the dryer.

Savings per MF unit are then multiplied by the #units served / #washers. Note only units without in-unit clothes washers should be counted.

For Residential grade units the savings per MF unit are consistent with assumptions in the Efficient Product measure (see measure for write up of savings methodology), however number of of cycles per year per unit is reduced from 265 (assumed for in-unit multi family) to 112 (common area multi family) as presented below.

For Commercial grade units savings are calculated as described below.

ΔkW	= ΔkW Per MF unit × NumUnits / NumWashers
Commercial Units Market Opportunity: $\Delta kW\ Per\ MF\ unit_{Com\ MO}$	= $\Delta kWh\ Per\ MF\ Unit_{Com\ MO}$ / Hours
Commercial Units Market Opportunity: $\Delta kW\ Per\ MF\ unit_{Com\ ER}$	= $\Delta kWh\ Per\ MF\ Unit_{Com\ ER}$ / Hours
Residential grade units: $\Delta kW\ Per\ MF\ Unit_{Res}$	= See table below of savings based on Efficient Products measure with lowered N_{Cycles} assumption

Symbol Table

Electric Energy Savings

ΔkWh	= ΔkWh Per MF Unit × NumUnits / NumWashers
Commercial Units Market Opportunity:	= (Capacity × 1/MEF_{J2}base × Ncycles × (%CWbase + (%DHWbase × %Electric_DHW) + (%Dryerbase × %Electric_Dryer))) - (Capacity × 1/MEF_{J2}eff × Ncycles × (%CWeff + (%DHWeff × %Electric_DHW) + (%Dryereff × %Electric_Dryer)))

ΔkWh Per MF Unit$_{Com\ MO}$	Dryereff × %Electric_Dryer)))
Commercial Units Early Replacement: ΔkWh Per MF Unit$_{Com\ ER}$	= (Capacity × 1/MEF$_{J2}$exist × Ncycles × (%CWbase + (%DHWbase × %Electric_DHW) + (%Dryerbase × %Electric_Dryer))) - (Capacity × 1/MEF$_{J2}$eff × Ncycles × (%CWeff + (%DHWeff × %Electric_DHW) + (%Dryereff × %Electric_Dryer)))
Residential grade units: ΔkWh Per MF Unit$_{Res}$	= See table below of savings based on Efficient Products measure with lowered N$_{Cycles}$ assumption

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= ΔMMBtu Per MF Unit × NumUnits / NumWashers
Commercial Units Market Opportunity: ΔMMBtu Per MF Unit$_{Com\ MO}$	= ((Capacity × 1/MEF$_{J2}$base × Ncycles × ((%DHWbase × %Fuel_DHW × R_eff) + (%Dryerbase × %Fuel_Dryer))) - (Capacity × 1/MEF$_{J2}$eff × Ncycles × ((%DHWeff × %Fuel_DHW × R_eff) + (%Dryereff × %Fuel_Dryer))))× MMBtu_convert
Commercial Units Early Replacement: ΔMMBtu Per MF Unit$_{Com\ ER}$	= ((Capacity × 1/MEF$_{J2}$exist × Ncycles × ((%DHWbase × %Fuel_DHW × R_eff) + (%Dryerbase × %Fuel_Dryer))) - (Capacity × 1/MEF$_{J2}$eff × Ncycles × ((%DHWeff × %Fuel_DHW × R_eff) + (%Dryereff × %Fuel_Dryer))))× MMBtu_convert
Residential grade units: ΔMMBtu Per MF Unit$_{Res}$	= See table below of savings based on Efficient Products measure with lowered N$_{Cycles}$ assumption

Symbol Table

Water Savings

ΔCCF	= ΔCCF per MF unit × NumUnits / NumWashers
Commercial Units Market Opportunity: ΔCCF Per MF unit$_{Com\ MO}$	= ((Capacity × (IWFbase - IWFeff)) × Ncycles) / GallonsPerCCF
Commercial Units Early Replacement: ΔCCF Per MF unit$_{Com\ ER}$	= ((Capacity × (IWFexist - IWFeff)) × Ncycles) / GallonsPerCCF
Residential grade units: ΔCCF Per MF unit$_{Res}$	= See table below of savings based on Efficient Products measure with lowered N$_{Cycles}$ assumption

Where:

%CWbase	=	= Percentage of total energy consumption used for operating Clothes Washer (baseline)[2] = 7%
%CWeff	=	= Percentage of total energy consumption used for operating Clothes Washer (efficient) = 3.9%
%DHWbase	=	= Percentage of total energy consumption used for water heating (baseline) = 28.1%
%DHWeff	=	= Percentage of total energy consumption used for water heating (efficient) = 15.5%
%Dryerbase	=	= Percentage of total energy consumption used for dryer operation (baseline) = 64.9%
%Dryereff	=	= Percentage of total energy consumption used for dryer operation (efficient) = 80.6%
%Electric_DHW	=	= Percentage of water savings assumed to be electric = (1 if electric, 0 if gas) Assumed to be known
%Electric_Dryer	=	= Percentage of dryer savings assumed to be electric = (1 if electric, 0 if gas) Assumed to be known
%Fuel_DHW	=	Percentage of DHW savings assumed to be non electric = (1 if natural gas, propane or oil, 0 if electric) Assumed to be known
%Fuel_Dryer	=	Percentage of dryer savings assumed to be non electric = (1 if natural gas or propane, 0 if electric) Assumed to be known
ΔCCF Per MF unit$_{Com\ ER}$	=	Gross annual customer water (CCF) savings per MF unit for a commercial grade clothes washer as an early replacement measure
ΔCCF Per MF unit$_{Com\ MO}$	=	Gross annual customer water (CCF) savings per MF unit for a commercial grade clothes washer as an market opportunity measure
ΔCCF Per MF unit$_{Res}$	=	Gross annual customer water (CCF) savings per MF unit for a residential grade clothes washer
ΔCCF per MF unit	=	Gross annual customer water (CCF) savings per MF unit
ΔCCF	=	annual *customer* water savings per clothes washer in CCF (hundreds of cubic feet)
ΔkW Per MF unit$_{Com\ ER}$	=	Gross annual customer kW savings per MF unit for a commercial grade clothes washer as an early replacement measure
ΔkW Per MF unit$_{Com\ MO}$	=	Gross annual customer kW savings per MF unit for a commercial grade clothes washer as market opportunity measure
ΔkW Per MF Unit$_{Res}$	=	Gross annual customer kW savings per MF unit for a residential grade clothes washer.
ΔkW Per MF unit	=	Gross annual customer kW savings per MF unit
ΔkW	=	Gross annual customer kW savings per clothes washer for the measure
ΔkWh Per MF Unit$_{Com\ ER}$	=	Gross annual customer kWh savings per MF unit for a commercial grade clothes washer as an early replacement measure
ΔkWh Per MF Unit$_{Com\ MO}$	=	Gross annual customer kWh savings per MF unit for a commercial grade clothes washer as a market opportunity measure
ΔkWh Per MF Unit$_{Res}$	=	Gross annual customer kWh savings per MF unit for a residential grade clothes washer.

ΔkWh Per MF Unit	=	Gross annual customer kWh savings per MF unit
ΔkWh	=	Gross annual customer kWh savings per clothes washer for the measure
ΔMMBtu Per MF $Unit_{Com\ ER}$	=	Gross annual customer MMBtu savings per MF unit for a commercial grade clothes washer as an early replacement measure
ΔMMBtu Per MF $Unit_{Com\ MO}$	=	Gross annual customer MMBtu savings per MF unit for a commercial grade clothes washer as a market opportunity measure
ΔMMBtu Per MF $Unit_{Res}$	=	Gross annual customer MMBtu savings per MF unit for a residential grade clothes washer.
ΔMMBtu Per MF Unit	=	Gross annual customer MMBtu savings per MF unit
ΔMMBtu	=	Gross annual customer MMBtu savings per clothes washer for the measure
Capacity	=	= Clothes Washer capacity (cubic feet) = 3.3 cu ft[3]
GallonsPerCCF	=	Gallons per CCF =748
Hours	=	assumed annual run hours of clothes washer per MF unit = 112[1]
IWFbase	=	Integrated Water Factor of baseline unit = 4.1 IWF for front loading units and 8.8 IWF for top loading units
IWFeff	=	Integrated Water Factor of efficient unit = 4.0 IWF
IWFexist	=	Integrated Water Factor of existing unit = 9.8 IWF for front loading units and 9.9 IWF for top loading units
MEF_{J2}base	=	Modified Energy Factor (based on Appendix J2 testing protocol) of baseline unit = 2.0 MEFfor front loading units and 1.35 MEFfor top loading units
MEF_{J2}eff	=	Modified Energy Factor (based on Appendix J2 testing protocol) of efficient unit = 2.2 MEF_{J2}
MEF_{J2}exist	=	Modified Energy Factor (based on Appendix J2 testing protocol) of existing unit = 1 MEF_{J2} for front loading machines and 0.84 MEF_{J2} for top-loading.
MMBtu_convert	=	Convertion factor from kWh to MMBtu (Constant) = 0.003413
Ncycles	=	Number of Cycles per year per unit = 112[4]
NumUnits	=	number of residential units (apartments) served by the central laundry facility
NumWashers	=	total number of clothes washers in central laundry facility
R_eff	=	Recovery efficiency factor = 1.26[5]

Load Shapes

134a MF Common Area Laundry

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
134	MF Common Area Laundry	Active	42.0%	28.8%	16.9%	12.3%	11.6%	8.7%

Net Savings Factors

Measures

CKLESWRP	Energy Star Clothes Washer
CKLCWASH	Commercial efficient clothes washer
CKLC2WRP	Energy Star clothes washer CEE Tier 2

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES
6020CUST [is base track]	6020CUST

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	CKLESWRP	1.00	1.00
LIMF NC	6018LINC	CKLCWASH	1.00	1.00
LIMF NC	6018LINC	CKLC2WRP	1.00	1.00
MF Mkt NC	6019MFNC	CKLESWRP	0.95	1.00
MF Mkt NC	6019MFNC	CKLCWASH	0.95	1.00
MF Mkt NC	6019MFNC	CKLC2WRP	0.95	1.00
6017PRES	6017PRES	CKLESWRP	1.00	1.00
6017PRES	6017PRES	CKLCWASH	1.00	1.00
6017PRES	6017PRES	CKLC2WRP	1.00	1.00
6017CUST	6017CUST	CKLESWRP	1.00	1.00
6017CUST	6017CUST	CKLCWASH	1.00	1.00
6017CUST	6017CUST	CKLC2WRP	1.00	1.00
6020PRES	6020PRES	CKLESWRP	0.90	1.00
6020PRES	6020PRES	CKLCWASH	0.90	1.00
6020PRES	6020PRES	CKLC2WRP	0.90	1.00
6020CUST	6020CUST	CKLESWRP	0.90	1.00
6020CUST	6020CUST	CKLCWASH	0.90	1.00
6020CUST	6020CUST	CKLC2WRP	0.90	1.00

Lifetimes

14 years[6] (same as in DPS screening of Efficiency Utility programs).

Early Replacement: The existing unit is assumed to have a remaining life of 3 years.

Analysis period is the same as the lifetime.

Measure Cost

The measure cost for this measure is provided below:

	Residential Grade[7]		Commercial Grade[8]	
Efficiency Level	Market Opportunity Incremental Cost	Early Replacement Full Install Cost	Market Opportunity Incremental Cost	Early Replacement Full Install Cost
ENERGY STAR	$124	$1,263	$942	$2,095
CEE TIER 2	$170	$1,309	N/A	N/A

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 3 years had the existing unit not been replaced is assumed to be $1,139 for Residential grade and $1,153 for Commercial grade.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Reference Tables

Customer Energy Savings Per MF Unit served, by Water Heater and Dryer Fuel Type[9]

Item Codes provided at end.

Market Opportunity:

Electric Savings:

Efficiency Level	Dryer/DHW Fuel Combo	RES GRADE ΔkWH Per MF unit Weighted Average	COMMERCIAL GRADE ΔkWH Per MF unit Weighted Average	RES GRADE ΔkW Per MF unit Weighted Average	COMMERCIAL GRADE ΔkW Per MF unit Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	44.2	91.8	0.3947	0.8193
	Electric Dryer/Fuel DHW	44.5	45.2	0.3970	0.4032
	Fuel Dryer/Electric DHW	9.4	58.3	0.0842	0.5201
	Fuel Dryer/Fuel DHW	9.7	11.7	0.0865	0.1040
CEE TIER 2	Electric Dryer/Electric DHW	94.6	n/a	0.8443	n/a
	Electric Dryer/Fuel DHW	47.6	n/a	0.4254	n/a
	Fuel Dryer/Electric DHW	51.9	n/a	0.4631	n/a
	Fuel Dryer/Fuel DHW	4.9	n/a	0.0442	n/a

MMBtu Savings:

Efficiency Level	Fuel Claimed	Configuration	RES GRADE ΔMMBtu Per MF unit Weighted Average	COMMERCIAL GRADE ΔMMBtu Per MF unit Weighted Average
ENERGY STAR	n/a	Electric Dryer/Electric DHW	0.00	0.00
	Propane	Electric Dryer/Propane DHW	0.00	0.20
	Natural Gas	Electric Dryer/Natural Gas DHW	0.00	0.20
	Oil	Electric Dryer/Oil DHW	0.00	0.20
	Propane	Propane Dryer/Electric DHW	0.12	0.11
	Propane	Propane Dryer/Propane DHW	0.12	0.31
	Oil	Propane Dryer/Oil DHW	0.12	0.31
	Natural Gas	Natural Gas Dryer/Electric DHW	0.12	0.11
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	0.12	0.31
	Oil	Natural Gas Dryer/Oil DHW	0.12	0.31
CEE TIER 2	n/a	Electric Dryer/Electric DHW	0.00	n/a
	Propane	Electric Dryer/Propane DHW	0.20	n/a
	Natural Gas	Electric Dryer/Natural Gas DHW	0.20	n/a
	Oil	Electric Dryer/Oil DHW	0.20	n/a
	Propane	Propane Dryer/Electric DHW	0.15	n/a
	Propane	Propane Dryer/Propane DHW	0.35	n/a
	Oil	Propane Dryer/Oil DHW	0.35	n/a
	Natural Gas	Natural Gas Dryer/Electric DHW	0.15	n/a
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	0.35	n/a
	Oil	Natural Gas Dryer/Oil DHW	0.35	n/a

Water Savings:

Efficiency Level	RES GRADE ΔCCF Per MF unit Weighted Average	COMMERCIAL GRADE ΔCCF Per MF unit Weighted Average
ENERGY STAR	0.5	2.1
CEE TIER 2	1.0	n/a

Early Replacement:

Electric Savings:

Efficiency Level	Dryer/DHW Fuel Combo	RES GRADE ΔkWH Per MF unit replacing:		RES GRADE Mid Life Adjustment Replacing:		COMMERCIAL GRADE ΔkWH Per MF unit replacing:		COMMERCIAL GRADE Mid Life Adjustment Replacing:		RES GRADE ΔkW Per MF unit replacing:		COMMERCIAL GRADE ΔkW Per MF unit replacing:	
		Front	Top	Front	Top	Front	Top	Front	Top	Front	Top	Front	Top
ENERGY STAR	Electric Dryer/Electric DHW	299.5	416.3	15%	11%	199.0	268.5	46%	34%	2.674	3.717	1.777	2.397
	Electric Dryer/Fuel DHW	252.5	215.7	18%	21%	122.3	172.2	37%	26%	2.254	1.926	1.092	1.538
	Fuel Dryer/Electric DHW	78.4	210.6	12%	4%	95.9	120.3	61%	48%	0.700	1.881	0.856	1.074
	Fuel Dryer/Fuel DHW	31.4	10.1	31%	96%	19.2	24.1	61%	48%	0.281	0.090	0.171	0.215
CEE TIER 2	Electric Dryer/Electric DHW	349.9	466.6	27%	20%	n/a	n/a	n/a	n/a	3.124	4.166	n/a	n/a
	Electric Dryer/Fuel DHW	255.7	218.9	19%	22%	n/a	n/a	n/a	n/a	2.283	1.954	n/a	n/a
	Fuel Dryer/Electric DHW	120.9	253.1	43%	20%	n/a	n/a	n/a	n/a	1.079	2.260	n/a	n/a
	Fuel Dryer/Fuel DHW	26.7	5.3	19%	93%	n/a	n/a	n/a	n/a	0.238	0.048	n/a	n/a

MMBtu Savings:

Efficiency Level	Fuel Claimed	Configuration	RES GRADE ΔMMBtu Per MF unit replacing:		RES GRADE Mid Life Adjustment Replacing:		COMMERCIAL GRADE ΔMMBtu Per MF unit replacing:		COMMERCIAL GRADE Mid Life Adjustment Replacing:	
			Front	Top	Front	Top	Front	Top	Front	Top
ENERGY STAR	n/a	Electric Dryer/Electric DHW	0.00	0.00	n/a	n/a	0.00	0.00	n/a	n/a
	Propane	Electric Dryer/Propane DHW	0.20	0.86	-1%	0%	0.33	0.41	61%	48%
	Natural Gas	Electric Dryer/Natural Gas DHW	0.20	0.86	-1%	0%	0.33	0.41	61%	48%
	Oil	Electric Dryer/Oil DHW	0.20	0.86	-1%	0%	0.33	0.41	61%	48%
	Propane	Propane Dryer/Electric DHW	0.75	0.70	16%	17%	0.35	0.51	33%	23%
	Propane	Propane Dryer/Propane DHW	0.96	1.56	12%	8%	0.68	0.92	46%	34%
	Oil	Propane Dryer/Oil DHW	0.96	1.56	12%	8%	0.68	0.92	46%	34%
	Natural Gas	Natural Gas Dryer/Electric DHW	0.75	0.70	16%	17%	0.35	0.51	33%	23%
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	0.96	1.56	12%	8%	0.68	0.92	46%	34%
	Oil	Natural Gas Dryer/Oil DHW	0.96	1.56	12%	8%	0.68	0.92	46%	34%
CEE TIER	n/a	Electric Dryer/Electric DHW	0.00	0.00	n/a	n/a	n/a	n/a	n/a	n/a
	Propane	Electric Dryer/Propane DHW	0.40	1.07	50%	19%	n/a	n/a	n/a	n/a
	Natural Gas	Electric Dryer/Natural Gas DHW	0.40	1.07	50%	19%	n/a	n/a	n/a	n/a
	Oil	Electric Dryer/Oil DHW	0.40	1.07	50%	19%	n/a	n/a	n/a	n/a
	Propane	Propane Dryer/Electric DHW	0.78	0.73	19%	20%	n/a	n/a	n/a	n/a

2	Propane	Propane Dryer/Propane DHW	1.19	1.79	29%	19%	n/a	n/a	n/a	n/a
	Oil	Propane Dryer/Oil DHW	1.19	1.79	29%	19%	n/a	n/a	n/a	n/a
	Natural Gas	Natural Gas Dryer/Electric DHW	0.78	0.73	19%	20%	n/a	n/a	n/a	n/a
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	1.19	1.79	29%	19%	n/a	n/a	n/a	n/a
	Oil	Natural Gas Dryer/Oil DHW	1.19	1.79	29%	19%	n/a	n/a	n/a	n/a

Water savings:

The weighted average savings are provided below, based on weighting the first year savings for 3 years and the reduced savings for the remaining 11 years. Note the screening tool currently does not allow mid life adjustments to be applied to water savings.

Efficiency Level	RES GRADE ΔCCF Per MF unit replacing:		COMMERCIAL GRADE ΔCCF Per MF unit replacing:	
	Front Weighted Average	Top Weighted Average	Front Weighted Average	Top Weighted Average
ENERGY STAR	0.8	0.7	2.3	2.3
CEE TIER 2	1.3	1.3	n/a	n/a

Market Opportunity Item Codes:

Efficiency Level	Fuel Claimed	Configuration	RES GRADE	COMMERCIAL GRADE
			Weighted Average	Weighted Average
ENERGY STAR	n/a	Electric Dryer/Electric DHW	MFCRCKLESAEEWRP	MFCCCKLESAEEWRP
	Propane	Electric Dryer/Propane DHW	MFCRCKLESAELWRP	MFCCCKLESAELWRP
	Natural Gas	Electric Dryer/Natural Gas DHW	MFCRCKLESAENWRP	MFCCCKLESAENWRP
	Oil	Electric Dryer/Oil DHW	MFCRCKLESAEOWRP	MFCCCKLESAEOWRP
	Propane	Propane Dryer/Electric DHW	MFCRCKLESALEWRP	MFCCCKLESALEWRP
	Propane	Propane Dryer/Propane DHW	MFCRCKLESALLWRP	MFCCCKLESALLWRP
	Oil	Propane Dryer/Oil DHW	MFCRCKLESALOWRP	MFCCCKLESALOWRP
	Natural Gas	Natural Gas Dryer/Electric DHW	MFCRCKLESANEWRP	MFCCCKLESANEWRP
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	MFCRCKLESANNWRP	MFCCCKLESANNWRP
	Oil	Natural Gas Dryer/Oil DHW	MFCRCKLESANOWRP	MFCCCKLESANOWRP
CEE TIER 2	n/a	Electric Dryer/Electric DHW	MFCRCKLT2AEEWRP	n/a
	Propane	Electric Dryer/Propane DHW	MFCRCKLT2AELWRP	n/a
	Natural Gas	Electric Dryer/Natural Gas DHW	MFCRCKLT2AENWRP	n/a
	Oil	Electric Dryer/Oil DHW	MFCRCKLT2AEOWRP	n/a
	Propane	Propane Dryer/Electric DHW	MFCRCKLT2ALEWRP	n/a
	Propane	Propane Dryer/Propane DHW	MFCRCKLT2ALLWRP	n/a
	Oil	Propane Dryer/Oil DHW	MFCRCKLT2ALOWRP	n/a
	Natural Gas	Natural Gas Dryer/Electric DHW	MFCRCKLT2ANEWRP	n/a
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	MFCRCKLT2ANNWRP	n/a
	Oil	Natural Gas Dryer/Oil DHW	MFCRCKLT2ANOWRP	n/a

Early Replacement Item Codes:

Efficiency Level	Fuel Claimed	Configuration	RES GRADE ΔMMBtu Per MF unit		COMMERCIAL GRADE ΔMMBtu Per MF unit	
			Front	Top	Front	Top
ENERGY STAR	n/a	Electric Dryer/Electric DHW	MFCRCWESFEREE	MFCRCWESTEREE	MFCCCWESFEREE	MFCCCWESTEREE
	Propane	Electric Dryer/Propane DHW	MFCRCWESFEREL	MFCRCWESTEREL	MFCCCWESFEREL	MFCCCWESTEREL
	Natural Gas	Electric Dryer/Natural Gas DHW	MFCRCWESFEREN	MFCRCWESTEREN	MFCCCWESFEREN	MFCCCWESTEREN
	Oil	Electric Dryer/Oil DHW	MFCRCWESFEREO	MFCRCWESTEREO	MFCCCWESFEREO	MFCCCWESTEREO
	Propane	Propane Dryer/Electric DHW	MFCRCWESFERPE	MFCRCWESTERPE	MFCCCWESFERPE	MFCCCWESTERPE
	Propane	Propane Dryer/Propane DHW	MFCRCWESFERPP	MFCRCWESTERPP	MFCCCWESFERPP	MFCCCWESTERPP
	Oil	Propane Dryer/Oil DHW	MFCRCWESFERPO	MFCRCWESTERPO	MFCCCWESFERPO	MFCCCWESTERPO
	Natural Gas	Natural Gas Dryer/Electric DHW	MFCRCWESFERNE	MFCRCWESTERNE	MFCCCWESFERNE	MFCCCWESTERNE
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	MFCRCWESFERNN	MFCRCWESTERNN	MFCCCWESFERNN	MFCCCWESTERNN
	Oil	Natural Gas Dryer/Oil DHW	MFCRCWESFERNO	MFCRCWESTERNO	MFCCCWESFERNO	MFCCCWESTERNO
CEE TIER 2	n/a	Electric Dryer/Electric DHW	MFCRCWT2FEREE	MFCRCWT2TEREE	n/a	n/a
	Propane	Electric Dryer/Propane DHW	MFCRCWT2FEREL	MFCRCWT2TEREL	n/a	n/a
	Natural Gas	Electric Dryer/Natural Gas DHW	MFCRCWT2FEREN	MFCRCWT2TEREN	n/a	n/a
	Oil	Electric Dryer/Oil DHW	MFCRCWT2FEREO	MFCRCWT2TEREO	n/a	n/a
	Propane	Propane Dryer/Electric DHW	MFCRCWT2FERPE	MFCRCWT2TERPE	n/a	n/a
	Propane	Propane Dryer/Propane DHW	MFCRCWT2FERPP	MFCRCWT2TERPP	n/a	n/a
	Oil	Propane Dryer/Oil DHW	MFCRCWT2FERPO	MFCRCWT2TERPO	n/a	n/a
	Natural Gas	Natural Gas Dryer/Electric DHW	MFCRCWT2FERNE	MFCRCWT2TERNE	n/a	n/a
	Natural Gas	Natural Gas Dryer/Natural Gas DHW	MFCRCWT2FERNN	MFCRCWT2TERNN	n/a	n/a
	Oil	Natural Gas Dryer/Oil DHW	MFCRCWT2FERNO	MFCRCWT2TERNO	n/a	n/a

Footnotes

[1] Assumes 1 hour per cycle.

[2] All base and efficient energy breakdown are based on ENERGY STAR Commercial Appliance calculator assumptions. See "MF Common Area Commercial Clothes Washer 2020.xls".

[3] Based on average capacity from CEC Database for commercial grade clothes washers, accessed 2/2020. See "MF Common Area Commercial Clothes Washer 2020.xls".

[4] A 2001 National Research Study: "A National Study of Water & Energy Consumption in Multifamily Housing; In-Apartment Washers vs Common Area Laundry rooms", found that residents with in-unit washers do 5.22 loads per week on average, while residents using common area laundry do 2.16 loads per week.

[5] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency). Therefore a factor of 0.98/0.78 (1.26) is applied.

[6] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool.

[7] Based on inflating cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See Efficient Product measure

[8] Incremental cost is based on weighted average incremental costs (90% moving from inefficeint top loader to high efficient front loader, and 10% moving from inefficient front loader to high efficient front loader) from NRDC, SAHF: "Efficiency Opportunities in Multifamily Common Area Laundry Facilities". Baseline costs were esimtated using an internet shop and then full install cost estimated by adding baseline and incremental. See 'MF Common Area Commercial Clothes Washer 2020.xls' for calculation.

[9] Where dryer and DHW use different fossil fuels, savings are combined under the DHW fossil fuel because a single measure can only have one fuel type for screening purposes and the DHW savings are larger than the Dryer savings.

ENERGY STAR Clothes Dryer

Measure Number: IV-A-2 d
Portfolio: EVT TRM Portfolio 2019-01
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Laundry

Update Summary

- Re-analysis of savings based on units participating in the EVT Program.
- Addition of Compact units and savings.
- Removal of Emerging Technology Award as a category and replacing with ENERGY STAR Most Efficient Hybrid (Standard sized) and ENERGY STAR Most Efficient Full Heat Pump (compact sized).
- Removal of gas dryers.

Applicable Markets

Applicable Markets
Efficient Products
Residential New Construction
Multifamily In Unit New Construction
Multifamily In Unit Retrofit
Low Income Single Family Retrofit
Existing Homes Retrofit

Referenced Documents

- 2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses
- ENERGY STAR Draft 2 Version 1
- ENERGY STAR Final Version 1 0 Clothes Dryers Program Requirements
- Appendix J2 To Subpart B Of Part 430—Uniform Test Method For Measuring The Energy Consumption Of automatic And Semi-Automatic Clothes Washers
- ENERGY STAR Dryer Specification NEEA Amended comments Mar 26 2013
- VT SF Existing Homes Onsite Report - DRAFT 122117
- 2018 Clothes Dryer Analysis_ v2

Description

Clothes dryers exceeding minimum qualifying efficiency for ENERGY STAR (standard sized or compact), ENERGY STAR Most Efficient Hybrid Heat Pumps (all standard sized) and ENERGY STAR Most Efficient Full Heat Pumps (all compact units), based on Combined Energy Factor (CEF), as described below under High Efficiency.

The CEF measures energy consumption of the total dryer cycle (standby usage, dryer heating and operation) in units of weight (lbs) of clothing dried per kWh of electricity; the higher the number, the greater the efficiency. In the case of gas dryers, the CEF combines both the gas and electric usage into a single CEF metric also measured in units of weight of clothing dried per kWh of electricity.

Baseline Efficiencies

Market Opportunity:

The baseline combined energy factor (CEF) was derived in the ENERGY STAR Version 1.0 analysis by multiplying 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements. This gives 3.11 CEF for standard electric dryers, 3.01 for compact 120V dryers, 2.73 for vented 240V dryers and 2.13 for compact ventless dryers.

Early Replacement:

The baseline in this case is the efficiency of the existing unit for its assumed remaining life (4 years) and the new baseline as defined above for the remainder of the measure (remaining 8 years). The Federal baseline for clothes dryers prior to 2015 had been in place since 1994. The standard was 3.01 EF for electric units. Comparing new units Combined Energy Factor (which include accounting for standby loads in addition to active drying energy) with older units Energy Factor (which only accounts for active drying energy) is challenging and complicated further by significant changes in testing procedures over the years. However, there hasn't been significant change in actual clothes dryer performance over the past decades and using these EF without any adjustment is consistent with this, only representing approximately 3% lower efficiency than the new baseline, and is used as an estimate of existing unit efficiency.

Applying the same ratio of old standard to new is applied to the new standard for compact units to estimate an existing baseline of 2.91CEF for compact 120V dryers, 2.64 for vented 240V dryers and 2.06 for compact ventless dryers. .

Efficient Equipment

High efficiency is defined as any model meeting or exceeding ENERGY STAR or ENERGY STAR Most Efficient criteria, as defined in the following table:

	Combined Energy Factor (CEF) Lbs / kWh	
	ENERGY STAR	ENERGY STAR Most Efficient
Standard Sized	>= 3.93	>= 4.3
Compact 120V	>= 3.8	>= 4.3
Compact 240V Ventled	>= 3.45	>= 4.3
Compact 240V Ventless	>=2.68	>= 3.7

Energy savings estimates are based on the resulting product from multiplying the average CEF of units purchased through the Efficiency Vermont program during 2017 and 2018. An additional waste heat calculation has been incorporated in to the final savings determination. This accounts for the unit's waste heat either being predominately vented to outside or remaining in the home and reducing the heating demands (notably in ventless hybrid and full heat pump models).

Algorithms

Electric Demand Savings

ΔkW	$= \Delta kWh/Hours$

Symbol Table

Electric Energy Savings

Market Opportunity: ΔkWh_{unit}	$= Weight \times (1/CEF_{base} - 1/CEF_{eff}) \times \%Washer \times N_{cycles}$
Early Replacement: ΔkWh_{unit}	$= Weight \times (1/CEF_{exist} - 1/CEF_{eff}) \times \%Washer \times N_{cycles}$
$\Delta kWh_{WasteHeat}$	$= \Delta kWh_{Heat} + \Delta kWh_{Cool}$ $\Delta kWh_{Heat} = kWh_{HeatBase} - kWh_{HeatEff}$

kWh_{Heat} = (%HeatSpace × WHHF × %HeatSource × %Conditioned × Dryer Consumption)/COPHeat

$\Delta kWh_{Cool} = kWh_{CoolBase} - kWh_{CoolEff}$

kWh_{Cool} = (%HeatSpace × WHCF × %Cooling × %Conditioned × Dryer Consumption)/COPCool

ΔkWh	= ΔkWhUnit + kWhVentless + ΔkWhWasteHeat

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu_{WasteHeat}$	$= MMBtu_{WasteHeatBase} - MMBtu_{WasteHeatEff}$ $MMBtu_{WasteHeat}$ = (%HeatSpace × WHHF × %HeatSource × %Conditioned × Dryer Consumption × 0.003412)/ ηHeat
ΔMMBtu	= ΔMMBtuVentless + ΔMMBtuWasteHeat

Where:

%Conditioned = Portion of homes with dryer in conditioned space

= 73%[2]

%Cooling = Percent of homes with central cooling

= 2%[3]

%HeatSource = Portion of homes with fuel source[4]:

Fuel Source	Portion of homes (%HeatSource)
Electric	2%
Natural Gas	12%
Propane gas	24%
Fuel Oil	35%
Wood	26%

%HeatSpace = Proportion of dryer heat energy remaining in space:

Unit Type	%HeatSpace
Vented	5%
Ventless	100%

%Washer = Reduction in dryer savings from efficient clothes washers[5]

= Values provided in table below

Efficiency Level	% Energy Reduction from Paired Efficient Washers
Vented Units	14%
Ventless Units	16%

ΔkWh = Total gross customer annual kWh savings for the measure

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh_{Cool} = Impact of waste heat on cooling loads

ΔkWh_{Heat} = Impact of waste heat on heating loads

ΔkWh_{unit} = Gross electric savings for operation of clothes dryer

$\Delta kWh_{WasteHeat}$ = Gross electric savings relating to waste heat impacts

ΔkWh = Total gross customer annual kWh savings for the measure

$\Delta MMBtu_{WasteHeat}$ = Heating impact associated with waste heat of unit

ΔMMBtu = Total gross fuel savings for the measure

ΔMMBtuVentless = HVAC In-direct fossil fuel savings from ventless dryer, by fuel type[14]

Values provided in table below for Ventless dryers; zero for all others

	Total MMBtu	NG	LP	Oil	Wood
Ventless Units	0.35	0.05	0.05	0.17	0.08

ΔMMBtuWasteHeat = Gross fuel savings relating to waste heat impacts

ηHeat = Efficiency of heating system[15]:

Fuel Source	Heating efficiency (ηHeat)
Natural Gas	89.1%
Propane gas	87.7%
Fuel Oil	82.9%
Wood	65%

ΔkWhUnit = Gross electric savings from operation of the clothes dryer

CEF_{base} = Combined Energy Factor of baseline unit based on full cycle testing of conventional dryers[6]

Values provided in table below

Efficiency Level	CEF (lbs/kWh)
STANDARD BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	3.11
COMPACT 120V BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	3.01
COMPACT Vented 240V BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	2.73
COMPACT Ventless 240V BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	2.13

CEF_{eff} = Combined Energy Factor of efficient unit

Values provided in table below[7]. Note categories indicating N/A do not currently have any product meeting the critera.

Efficiency Level	CEF

	(lbs/kWh)
Standard ENERGY STAR	3.93
Standard ENERGY STAR Most Efficient (Hybrid Heat Pump)	5.05
Standard Heat Pump	N/A
Compact 120V ENERGY STAR	N/A
Compact Vented 240V ENERGY STAR	N/A
Compact Ventless 240V ENERGY STAR	2.73
Compact 120V ENERGY STAR Most Efficient (Full Heat Pump)	7.02
Compact Vented 240V ENERGY STAR Most Efficient (Full Heat Pump)	N/A
Compact Ventless 240V ENERGY STAR Most Efficient (Full Heat Pump)	10.25

CEF_{exist} = Combined Energy Factor of existing unit[8]

Values provided in table below

Efficiency Level	CEF (lbs/kWh)
STANDARD BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	3.01
COMPACT 120V BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	2.91
COMPACT Vented 240V BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	2.64
COMPACT Ventless 240V BASELINE - ENERGY STAR Version 1.0 Estimated Baseline	2.06

COPCool = Coefficient of Performance of cooling system

= 3.0[9]

COPHeat = Coefficient of Performance of heating system

= 1.5[10]

Dryer Consumption = Estimated annual consumption of dryer used in calculation of waste heat impacts.

= Weight * 1/CEF * (1 - %Washer) * N

Hours = Assumed annual run hours of clothes dryer

= Ncycles * 1 Hour

= 322[1]

$kWh_{CoolBase}$ = Waste heat impacts on cooling for baseline unit

$kWh_{CoolEff}$ = Waste heat impacts on cooling for efficient unit

$kWh_{HeatBase}$ = Waste heat impacts on heating for baseline unit

$kWh_{HeatEff}$ = Waste heat impacts on heating for efficient unit

$kWh_{Ventless}$ = HVAC In-direct electric savings from ventless dryer not having to reheat make-up air[6739]

= 3 kWh for ventless dryers; 0 kWh for all others

$MMBtu_{WasteHeat}$ = Heating impact associated with waste heat of baseline or efficient unit

$MMBtu_{WasteHeatBase}$ = Waste heat impacts on heating for baseline unit

$MMBtu_{WasteHeatEff}$ = Waste heat impacts on heating for efficient unit

MMBtu_convert = Conversion factor from kWh to MMBtu

=0.003413

N_{cycles} = Number of Cycles per year

=322[11]

Weight = Average clothes dryer load weight (lbs) based on DOE average test load size of paired washer.

=10.4 lbs for standard units, 6.6 lbs for compact units[12]

WHCF = Portion of waste heat that results in increased cooling

= 0.188[13]

WHHF = Portion of reduced waste heat that results in increased heating

= 0.558[16]

Mid Life Savings Adjustment

The follow mid life savings adjustments are applied to the annual savings for early replacement measures after 4 years:

Efficiency Level	Electric Adjustment	Fossil Adjustment
ENERGY STAR	86%	94%
ENERGY STAR Most Efficient Hybrid	92%	100%
ENERGY STAR Most Efficient Full Heat Pump	96%	93%

Load Shapes

9a Residential Clothes Washer

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
9	Residential Clothes Washer	Active	42.0%	28.8%	16.9%	12.3%	4.4%	3.3%

Net Savings Factors

Measures

CKLESDRY	Energy Star Clothes Dryer
CKLESETA	Energy Star Most Efficient Clothes Dryer
CKLERESD	Early Replacement ENERGY STAR Clothes Dryer
CKLERETD	Energy Star Most Efficient Clothes Dryer, Early Replacement

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6036HPES [6036RETR]	HPwES EVT
6013EPEP [6032EPEP]	Efficient Products - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	CKLESDRY	0.90	1.10
Efficient Products - Residential	6032EPEP	CKLESETA	1.00	1.20
LISF Retrofit	6034LISF	CKLESDRY	1.00	1.00
LISF Retrofit	6034LISF	CKLESETA	1.00	1.00
Res Retrofit	6036RETR	CKLESDRY	0.90	1.00
Res Retrofit	6036RETR	CKLESETA	0.90	1.00
Efficient Products - Residential	6032EPEP	CKLERESD	1.00	1.00
LISF Retrofit	6034LISF	CKLERESD	1.00	1.00
Res Retrofit	6036RETR	CKLERESD	1.00	1.00
Efficient Products - Residential	6032EPEP	CKLERETD	1.00	1.00
LISF Retrofit	6034LISF	CKLERETD	1.00	1.00
Res Retrofit	6036RETR	CKLERETD	1.00	1.00

Lifetimes

12 years[17]

Analysis period is the same as the lifetime.

For early replacement the existing unit is assumed to have a remaining life of 4 years (1/3 of the measure life).

Measure Cost

The incremental cost and full install cost for this measure is provided in the table below[18]:

Efficiency Level	Market Opportunity Incremental Cost	Early Replacement Full Install Cost
ENERGY STAR	$61	$528
ENERGY STAR Most Efficient	$412	$879

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 4 years had the existing unit not been replaced is assumed to be $467.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Prescriptive Savings Tables

Deemed savings for this measure are provided below. For ENERGY STAR it is the weighted (by product in program) average of Standard ENERGY STAR units and Compact 240V Ventless ENERGY STAR. ENERGY STAR Most Efficient Hybrid Heat Pump are all Standard sized. ENERGY STAR Most Efficient Full Heat Pump is the weighted (by product in program) average of Compact 120V Full Heat Pump and Compact 240V Ventless Full Heat Pump.

	Item Code	ΔkWh	ΔkW	ΔMMBtu			
				NG	LP	Oil	Wood
ENERGY STAR	EPCKLDRYES	195	0.6045	-0.003	-0.006	-0.010	-0.011
ENERGY STAR Most Efficient Hybrid	EPCKLDRYETA2	364	1.1313	0.14	0.27	0.43	0.46
ENERGY STAR Most Efficient Full Heat Pump	EPCKLDRYETA3	587	1.8229	-0.06	-0.13	-0.19	-0.12

For Early Replacment measures, the first four years will assume the following savings before applying the midlife adjustment provided above:

	Item Code	kWh	kW	MMBtu			
				NG	LP	Oil	Wood
ENERGY STAR	EHCKLDERES	226	0.7010	-0.004	-0.007	-0.011	-0.012
ENERGY STAR Most Efficient Hybrid	EHCKLDERBT	396	1.2284	0.14	0.27	0.43	0.46
ENERGY STAR Most Efficient Full Heat Pump	EHCKLDERHT	613	1.9033	-0.06	-0.13	-0.20	-0.13

Footnotes

[1] Approximately one hour per cycle based upon NEEA data, see Table 1, page 6 of 'NEEA comments on ENERGY STAR Dryer Specification'.

[2] NEEP Study found 16 of 22 sites had the dryer in a heated space; NEEP, Energy & Resource Solutions "Electric Dryer Baseline Research", p8.

http://www.neep.org/sites/default/files/Microsoft%20PowerPoint%20-%20NEEP%20Dryer%20Presentation%20Final%2003-30-15.pdf

[3] Based on 'Vermont Single-Family Existing Homes Onsite Report', NMR Group Inc, 2017, Table 55.

[4] Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 40. (NMR Group, Inc. 2017).

[5] The percentage of energy reduction reflects the amount of dryer energy already captured by the performance of efficient clothes washers. The effective performance of paired clothes washers for both the ENERGY STAR and ENERGY STAR Most Efficient dryers reflect the market share and relative remaining moisture content for clothes washers both in-program (rebated) and out-of-program (non-rebated). See "2018 Clothes Dryer Analysis_v2.xlsx" tab "EVT Dryer Estimates" and "Washer Dryer Overlap".

[6] The baseline was derived in the ENERGY STAR Version 1.0 analysis by multiplying 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements. This gives 3.11 CEF for standard electric dryers, 3.01 for compact 120V dryers, 2.73 for vented 240V dryers and 2.13 for compact ventless dryers. See "2018 clothes dryer analysis_V2.xls" tabs "3. Elec. Standard Plot", "4. Elec. Compact 120V Plot" and "5. Elec Compact 240V Plot".

[7] Efficient unit CEF is based upon the average of units participating in the EP program in 2017 and 2018 that meet the relevent criteria. For Most Efficient units, to better reflect the performance of the units, the average NEEA laboratory testing results using the DOE Appendix D2 Test procedure were utilized. See '2017 to YTP 2018' tab in '2018 Clothes Dryer Analysis_v2.xls'.

[8] Based on the federal baseline for clothes dryers prior to 2015, which had been in place since 1994. The standard was 3.01 EF for standard electric units. The ratio of old standard to new is applied to the new standard for compact units to estimate an existing baseline.

[9] Average efficiency of AC system is 11.4 SEER (based on 'Vermont Single Family Existing Homes Onsite Report', NMR Group Inc, 2017, Table 55).
Convert to EER: (-0.02 * SEER2) + (1.12 * SEER) = 10.3 EER (calculation from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).
Convert to COP: EER/3.412 = 3.0 COP

[10] The COP used here is an assumption based upon a 50/50 split between resistance COP 1.0 and average Heat Pump effective COP of 2.0.

[11] [1] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization. A field evaluation completed by NEEA in 50 homes in the Northwest found a higher number of annual dryer cycles (337) than currently represented in the RECS data. Federal standard employs a 0.91 field use factor, based on RECS 2009 survey data suggesting not all clothes washer loads are dried. However, NEEA found a higher number of dryer loads, noting users may not have consolidated their loads to the extent EPA assumed.
http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

[12] Based on average of ENERGY STAR qualified dryers and available paired washer model capacity information. This average capacity is then used to look up the average load size in the U.S. DOE clothes washer test procedure (10 CFR 430, Subpart B, Appendix J2 Table 5.1), see 2018 Clothes Dryer Analysis_v2.xlsx

[13] Based on bin analysis of annual cooling hours for Burlington, VT using TMY3 data: 1650/8760 = 18.8%, see "2018 Clothes Dryer Analysis.xlsx"

[14] HVAC In-direct savings for ventless dryers are based on the penetration of heating fuel types and corresponding efficiencies identified in the 'Vermont Single-Family Existing Homes Onsite Report', NMR Group Inc, 2017, see "HVAC Inputs" tab in "2018 Clothes Dryer Analysis_V2.xlsx.

[15] Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 43, 46 and 47. (NMR Group, Inc. 2017). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves (U.S. Environmental Protection Agency n.d.)

[16] Based on bin analysis of annual heating hours for Burlington, VT using TMY3 data: 4885 / 8760 = 55.8%, see "Heating Penalty" tab in "2018 Clothes Dryer Analysis.xlsx"

[17] Based on average lifetime in DOE Buildings Data Book http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.15

[18] See "2018 Clothes Dryer Analysis_v2.xlsx", "Incremental Cost" tab. Based on DOE Life-Cycle Cost and Payback Period analysis Table 8.3.1, http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee12&disposition=attachment&contentType=pdf

Efficient Clothes Washers

Measure Number: RS-LAU-CKLW t
Portfolio: EVT TRM Portfolio 2019-10
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Laundry

Applicable Markets

Applicable Markets
Efficient Products
Residential New Construction
Multifamily In Unit New Construction
Multifamily In Unit Retrofit
Low Income Single Family Retrofit
Existing Homes Retrofit

Update Summary

Included a blended and weighted deemed savings table for a low income single-family voucher program. The voucher's have a value of $1,200 and the customer is responsible for any additional costs. Due to the make of the program, collecting dryer and DHW fuel information is not possible. Due to the program layout, assuming the majority of participants will be early replacement scenarios. The only revisions are in the addition of three deemed savings table under the early replacement options, kW, kWh, and MMBtu.

Referenced Documents

- Copy of EERE-2008-BT-STD-0019-0043
- VT SF Existing Homes Onsite Report - DRAFT 122117
- 2019 Clothes Washer Savings_ 08292019

Description

A new clothes washer exceeding minimum qualifying efficiency standards established as ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE Advanced Tier as of 1/1/2018, as defined below is purchased, installed in new construction (Market Opportunity) or is installed within an existing home having incentivized the early replacement of an inefficient unit (Early Replacement):

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR	>= 2.76	>= 2.06	<= 3.2	<= 4.3
CEE TIER 2	>= 2.92	n/a	<= 3.2	n/a
CEE ADVANCED TIER	>= 3.1	n/a	<= 3.0	n/a

The Integrated Modified Energy Factor (IMEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying) and the per-cycle standby and off mode energy consumption; the higher the number, the greater the efficiency.

The Integrated Water Factor (IWF) is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

In 2019, a low income single-family voucher program was incorporated into this measure's characterization. Customers will receiver a voucher that will cover the full cost of a new clothes washer, appliance delivery, and the removal of an existing unit, up to $1,200. The deemed savings for this program was specifically separated and put in their own table due to the implementation of the program where collecting dryer and DHW fuel information not possible. The savings in these table represented a weighted average of early replacement options leveraging fuel and equipment saturation from the, "Vermont Single-Family Existing Homes On-Site Report", NMR, December 2017.

Program Type

Calculation Type: Market Opportunity: Time of Sale / Market Opportunity: New Construction / Early Replacement

Program Delivery / Implementation Type: Downstream / Upstream

Baseline Efficiencies

Market Opportunity:

The baseline efficiency is determined according to the Integrated Modified Energy Factor (IMEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle and standby/off mode consumption. The Federal baseline IMEF as of January 2018 is 1.84 for front loading units and 1.57 for top loading units.

Early Replacement Baseline:

The baseline in this case is the efficiency of the existing unit for its assumed remaining life (3 years) and the new baseline as defined above for the remainder of the measure (remaining 11 years). Eligibility for this measure is limited to pre-2004 non-Energy Star units. The Federal baseline for clothes washers prior to 2004 was 0.817 MEF, and the average value of units tested in a 2001 DOE market assessment was 1.164MEF. Converting MEF to IMEF using an ENERGY STAR conversion tool copied in to the reference calculation spreadsheet "2019 Clothes Washer Savings.xls", provides the assumption for existing units of 0.74 IMEF for top-loading and 0.91 IMEF for front loading machines.

Efficient Equipment

High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or CEE Advanced Tier standards as of 2/5/2018, as provided in table above.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh/Hours

Symbol Table

Electric Energy Savings

ΔkWh	= (Capacity × 1/IMEFbase × Ncycles × (%CWbase + (%DHWbase × %Electric_DHW) + (%Dryerbase × %Electric_Dryer))) - (Capacity × 1/IMEFeff × Ncycles × (%CWeff + (%DHWeff × %Electric_DHW) + (%Dryereff × %Electric_Dryer)))

Symbol Table

Fossil Fuel Savings

ΔMMBtu	= ((Capacity × 1/IMEFbase × Ncycles × ((%DHWbase × %Fuel_DHW × R_eff) + (%Dryerbase × %Fuel_Dryer))) - (Capacity × 1/IMEFeff × Ncycles × ((%DHWeff × %Fuel_DHW× R_eff) + (%Dryereff × %Fuel_Dryer))))× MMBtu_convert

Symbol Table

Water Savings

ΔWater (CCF)	= ((Capacity × (IWFbase - IWFeff)) × Ncycles) / GallonsPerCCF

Where:

%CWbase	=	= Percentage of total energy consumption for baseline Clothes Washer operation (Deemed, dependent on efficiency level – see table below)

%CWef	=	= Percentage of total energy consumption for efficient Clothes Washer operation (Deemed, dependent on efficiency level – see table below)
%DHWbase	=	= Percentage of total energy consumption used for water heating by baseline unit (Deemed, dependent on efficiency level – see table below)
%DHWeff	=	= Percentage of total energy consumption used for water heating by efficient unit (Deemed, dependent on efficiency level – see table below)
%Dryerbase	=	= Percentage of total baseline energy consumption for dryer operation (Deemed, dependent on efficiency level – see table below)
%Dryereff	=	= Percentage of total efficient energy consumption for dryer operation (Deemed, dependent on efficiency level – see table below)

	Percentage of Total Energy Consumption[2]		
	%CW	%DHW	%Dryer
Federal Standard	8%	20%	72%
ENERGY STAR	5%	25%	70%
CEE TIER 2	10%	3%	87%
Advanced Tier	10%	3%	87%

%Electric_DHW = = Percentage of DHW savings assumed to be electric (Deemed, dependent on market)

Market	%Electric_DHW[3]
Efficient Products	25.0%
RNC	24% if unknown
Multifamily New Construction and Retrofit	Assumed always known

%Electric_Dryer = = Percentage of dryer savings assumed to be electric (Deemed, dependent on market)

Market	%Electric_Dryer[3]
Efficient Products	74.0%
RNC	76% if unknown
Multifamily New Construction and Retrofit	Assumed always known

%Fuel_DHW = = Percentage of DHW savings assumed to be non electric [3] (Deemed, dependent on market)

Market	DHW Fuel	%Fuel_DHW
Efficient Products	Natural Gas	26%
	Propane	27%
	Oil	20%
RNC	Natural Gas	14%
	Propane	52%
	Oil	10%
Multifamily New Construction and Retrofit	Assumed always known	

%Fuel_Dryer = = Percentage of dryer savings assumed to be Natural Gas[3]

(Deemed, dependent on market)

Market	Dryer fuel	%Gas_Dryer
Efficient Products	Natural Gas	11%
	LP Gas	15%
RNC	Natural Gas	8%
	LP Gas	16%
Multifamily New Construction	Assumed always known	

ΔkW	=	= gross customer connected load kW savings for the measure (Output)
ΔkWh	=	gross customer annual kWh savings for the measure (Output)
ΔMMBtu	=	= gross customer annual MMBtu savings for the measure (Output)
ΔWater (CCF)	=	= gross customer annual water savings for the measure (Output)
Capacity	=	= Clothes Washer capacity (cubic feet) = 4.13 [4] (Deemed) For Shift Model Approach only = Actual Rated Capacity[5]
GallonsPerCCF	=	Gallons per CCF =748
Hours	=	= assumed annual run hours of clothes washer (Deemed, dependent on market)

Market	Hours[1]
Single Family – Efficient Products, RNC	322
Multifamily	265

IMEFbase	=	= Integrated Modified Energy Factor of baseline unit = Values provided in table below; Federal Standard for Market Opportunity and Existing Unit for Early Replacement (Deemed, dependent on application) For Shift Model Approach only = Actual Rated IMEF[5]
IMEFeff	=	=Integrated Modified Energy Factor of efficient unit = Values provided in table below (Deemed, dependent on efficiency level) For Shift Model Approach only = Actual Rated IMEF[5]
IWFbase	=	= Integrated Water Factor of baseline clothes washer = Values provided below; Federal Standard for Market Opportunity and Existing Unit for Early Replacement (Deemed, dependent on application) For Shift Model Approach only = Actual Rated IWF[5]
IWFeff	=	=Integrated Water Factor of efficient unit = Values provided in table below (Deemed, dependent on efficiency level) For Shift Model Approach only = Actual Rated IWF[5]

MMBtu_convert = = Convertion factor from kWh to MMBtu (Constant)

= 0.003413

Ncycles = = Number of Cycles per year (Deemed, dependent on market)

Market	Ncycles
Single Family – Efficiency Products, RNC	322[6]
Multifamily	265[7]

R_eff = = Recovery efficiency factor (Deemed)

= 1.26[8]

Mid-Life Savings Adjustment

For mid-life savings adjustments, please see the reference tables below.

Load Shapes

9a Residential Clothes Washer

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
9	Residential Clothes Washer	Active	42.0%	28.8%	16.9%	12.3%	4.4%	3.3%

Net Savings Factors

Measures

CKLESWRP	Energy Star Clothes Washer
CKLESWER	Energy Star washer, early replacement
CKLT2WER	Energy Star Clothes Washer CEE 2 Early Replacement
CKLT3WER	Energy Star Clothes Washer CEE 3 Early Replacement
CKLC2WRP	Energy Star clothes washer CEE Tier 2
CKLC3WRP	Energy Star clothes washer CEE Tier 3

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
6017PRES [is base track]	6017PRES
6020PRES [is base track]	6020PRES
6013EPEP [6032EPEP]	Efficient Products - Commercial

Lifetimes

14 years[9](same as DPS screening of Efficiency Utility program).

Analysis period is the same as the lifetime. Early Replacement: The existing unit is assumed to have a remaining life of 3 years.

Measure Cost

The incremental cost for this measure is provided in the table below[10]:

Efficiency Level	Market Opportunity Incremental Cost	Early Replacement Full Install Cost
ENERGY STAR	$124	$1,263
CEE TIER 2	$170	$1,309
CEE Advanced Tier	$179	$1,318

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 3 years had the existing unit not been replaced is assumed to be $1,139.

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Prescriptive Savings Tables

The following tables provide the Prescriptive Savings values. See '2019 Clothes Washer Analysis_01082019.xls' for details.

kWh Savings

Market Opportunity:

The prescriptive kWH savings based on values provided above where DHW and Dryer fuels are unknown is provided below[11]:

Efficiency Level	Efficient Products ΔkWH						RNC ΔkWH			
	Front	Item Code	Top	Item Code	Weighted Average	Item Code	Front	Top	Weighted Average	Item Code
ENERGY STAR	118.9	EPESFCW	95.0	EPESTCW	101.6	EPESACW	119.6	97.5	103.6	RNCCKLESAWRP
CEE TIER 2	138.8	EPT2FCW	n/a	n/a	138.8	EPT2ACW	139.9	n/a	139.9	RNCCKLT2AWRP
CEE ADVANCED TIER	158.6	EPT3FCW	n/a	n/a	158.6	EPT3ACW	160.2	n/a	160.2	RNCCKLT3AWRP

The unit specific kWh savings when DHW and Dryer fuels are known is provided below (see MMBtu table for Item Codes):

Efficiency Level	Dryer/DHW Fuel Combo	RNC ΔkWH			Multifamily New Construction In Unit ΔkWH		
		Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	245.4	81.7	127.1	201.6	67.2	104.4
	Electric Dryer/Fuel DHW	111.3	134.1	127.8	91.5	110.2	105.0
	Fuel Dryer/Electric DHW	145.7	-18.3	27.1	119.8	-15.1	22.3
	Fuel Dryer/Fuel DHW	11.6	34.0	27.8	9.6	28.0	22.9
CEE TIER 2	Electric Dryer/Electric DHW	271.8	n/a	271.8	223.3	n/a	223.3
	Electric Dryer/Fuel DHW	137.0	n/a	137.0	112.5	n/a	112.5
	Fuel Dryer/Electric DHW	149.1	n/a	149.1	122.5	n/a	122.5
	Fuel Dryer/Fuel DHW	14.2	n/a	14.2	11.7	n/a	11.7
CEE ADVANCED TIER	Electric Dryer/Electric DHW	298.2	n/a	298.2	245.1	n/a	245.1
	Electric Dryer/Fuel DHW	162.7	n/a	162.7	133.6	n/a	133.6
	Fuel Dryer/Electric DHW	152.4	n/a	152.4	125.2	n/a	125.2

	Fuel Dryer/Fuel DHW	16.8	n/a	16.8	13.8	n/a	13.8

Early Replacement:

The first year savings are provided below, with a mid life adjustment to be applied after 3 years to bring the savings in line with a new replacement as provided above[12](see MMBtu table for Item Codes):

Efficiency Level	Dryer/DHW Fuel Combo	Single Family Early Replacement ΔkWH Replacing:			Multifamily In Unit Early Replacement ΔkWH Replacing:			Mid Life Adjustment Replacing:		
		Front	Top	Weighted Average	Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	860.9	1196.5	872.7	707.3	983.1	717.0	15%	11%	15%
	Electric Dryer/Fuel DHW	725.8	620.0	722.0	596.3	509.4	593.3	18%	21%	18%
	Fuel Dryer/Electric DHW	225.5	605.5	238.8	185.2	497.5	196.2	12%	4%	11%
	Fuel Dryer/Fuel DHW	90.4	29.0	88.2	74.3	23.8	72.5	31%	96%	32%
CEE TIER 2	Electric Dryer/Electric DHW	1005.6	1341.2	1017.4	826.3	1102.0	836.0	27%	20%	27%
	Electric Dryer/Fuel DHW	734.9	629.1	731.2	603.9	516.9	600.8	19%	22%	19%
	Fuel Dryer/Electric DHW	347.4	727.4	360.8	285.5	597.7	296.5	43%	20%	41%
	Fuel Dryer/Fuel DHW	76.8	15.4	74.6	63.1	12.6	61.3	19%	93%	19%
CEE ADVANCED TIER	Electric Dryer/Electric DHW	1032.1	1367.7	1043.9	848.0	1123.7	857.7	29%	22%	29%
	Electric Dryer/Fuel DHW	760.6	654.8	756.9	625.0	538.0	621.9	21%	25%	21%
	Fuel Dryer/Electric DHW	350.8	730.8	364.2	288.2	600.4	299.2	43%	21%	42%
	Fuel Dryer/Fuel DHW	79.3	18.0	77.2	65.2	14.8	63.4	21%	94%	22%

Efficiency Level	Item Code	Low Income Single Family Voucher Program ΔkWH			Mid Life Adjustment Replacing:		
		Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	LICWESVOU	595.0	613.4	609.3	19%	32%	29%
CEE TIER 2	LICWT2VOU	632.9	651.2	632.9	22%	35%	22%
CEE ADVANCED TIER	LICWT3VOU	652.7	671.1	652.7	24%	37%	24%

Market Opportunity:
kW Savings:

The prescriptive kW savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	Efficient Products ΔkW			RNC ΔkW		
	Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	0.369	0.295	0.316	0.371	0.303	0.322
CEE TIER 2	0.431	n/a	0.431	0.434	n/a	0.434
CEE ADVANCED TIER	0.493	n/a	0.493	0.498	n/a	0.498

The unit specific kW savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Dryer/DHW Fuel Combo	RNC ΔkW			Multifamily New Construction In Unit ΔkW		
		Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	0.762	0.254	0.395	0.762	0.254	0.395
	Electric Dryer/Fuel DHW	0.346	0.417	0.397	0.346	0.417	0.397
	Fuel Dryer/Electric DHW	0.453	-0.057	0.084	0.453	-0.057	0.084
	Fuel Dryer/Fuel DHW	0.036	0.106	0.086	0.036	0.106	0.086
CEE TIER 2	Electric Dryer/Electric DHW	0.844	n/a	0.844	0.844	n/a	0.844
	Electric Dryer/Fuel DHW	0.425	n/a	0.425	0.425	n/a	0.425
	Fuel Dryer/Electric DHW	0.463	n/a	0.463	0.463	n/a	0.463
	Fuel Dryer/Fuel DHW	0.044	n/a	0.044	0.044	n/a	0.044
CEE ADVANCED TIER	Electric Dryer/Electric DHW	0.926	n/a	0.926	0.926	n/a	0.926
	Electric Dryer/Fuel DHW	0.505	n/a	0.505	0.505	n/a	0.505
	Fuel Dryer/Electric DHW	0.473	n/a	0.473	0.473	n/a	0.473
	Fuel Dryer/Fuel DHW	0.052	n/a	0.052	0.052	n/a	0.052

Early Replacement:

The first year savings are provided below, with the mid life adjustment specified in the kWh table to be applied after 3 years to bring the savings in line with a new replacement as provided above:

Efficiency Level	Dryer/DHW Fuel Combo	Single Family Early Replacement ΔkW Replacing:			Multifamily In Unit Early Replacement ΔkW Replacing:		
		Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	2.674	3.717	2.711	2.674	3.717	2.711
	Electric Dryer/Fuel DHW	2.254	1.926	2.243	2.254	1.926	2.243
	Fuel Dryer/Electric DHW	0.700	1.881	0.742	0.700	1.881	0.742
	Fuel Dryer/Fuel DHW	0.281	0.090	0.274	0.281	0.090	0.274
CEE TIER 2	Electric Dryer/Electric DHW	3.124	4.166	3.160	3.124	4.166	3.160
	Electric Dryer/Fuel DHW	2.283	1.954	2.271	2.283	1.954	2.271
	Fuel Dryer/Electric DHW	1.079	2.260	1.121	1.079	2.260	1.121
	Fuel Dryer/Fuel DHW	0.238	0.048	0.232	0.238	0.048	0.232
CEE ADVANCED TIER	Electric Dryer/Electric DHW	3.206	4.248	3.243	3.206	4.248	3.243
	Electric Dryer/Fuel DHW	2.363	2.034	2.351	2.363	2.034	2.351
	Fuel Dryer/Electric DHW	1.090	2.270	1.131	1.090	2.270	1.131
	Fuel Dryer/Fuel DHW	0.246	0.056	0.240	0.246	0.056	0.240

Efficiency Level	Item Code	Low Income Single Family Voucher Program ΔkW		
		Front	Top	Weighted Average
ENERGY STAR	LICWESVOU	1.848	1.905	1.893
CEE TIER 2	LICWT2VOU	1.966	2.023	1.966
CEE ADVANCED TIER	LICWT3VOU	2.028	2.085	1.758

MMBTU Savings:

Market Opportunity:

The prescriptive MMBtu savings where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	Configuration	Efficient Products ΔMMBtu			RNC ΔMMBtu		
		NG	LP	Oil	NG	LP	Oil
ENERGY STAR	Front	0.19	0.21	0.12	0.11	0.35	0.06
	Top	-0.02	-0.01	-0.05	0.00	-0.06	-0.02
	Weighted Average	0.04	0.05	0.00	0.03	0.05	0.00
CEE TIER 2	Front	0.20	0.22	0.12	0.11	0.37	0.06
	Top	n/a	n/a	n/a	n/a	n/a	n/a
	Weighted Average	0.20	0.22	0.12	0.11	0.37	0.06
CEE ADVANCED TIER	Front	0.21	0.23	0.12	0.12	0.38	0.06
	Top	n/a	n/a	n/a	n/a	n/a	n/a
	Weighted Average	0.21	0.23	0.12	0.12	0.38	0.06

The unit specific MMBtu savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Configuration	Fuel Claimed	RNC ΔMMBtu				Multifamily New Construction In Unit ΔMMBtu		
			Front	Top	Weighted Average	Item Code	Front	Top	Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	n/a	0.00	0.00	0.00	RNCCKLESAEEWRP	0.00	0.00	0.00
	Electric Dryer/Propane DHW	Propane	0.58	-0.23	0.00	RNCCKLESAELWRP	0.47	-0.19	0.00
	Electric Dryer/Natural Gas DHW	Natural Gas	0.58	-0.23	0.00	RNCCKLESAENWRP	0.47	-0.19	0.00
	Electric Dryer/Oil DHW	Oil	0.58	-0.23	0.00	RNCCKLESAEOWRP	0.47	-0.19	0.00
	Propane Dryer/Electric DHW	Propane	0.34	0.34	0.34	RNCCKLESALEWRP	0.28	0.28	0.28
	Propane Dryer/Propane DHW	Propane	0.92	0.12	0.34	RNCCKLESALLWRP	0.75	0.10	0.28
	Propane Dryer/Oil DHW	Oil	0.92	0.12	0.34	RNCCKLESALOWRP	0.75	0.10	0.28
	Natural Gas Dryer/Electric DHW	Natural Gas	0.34	0.34	0.34	RNCCKLESANEWRP	0.28	0.28	0.28
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	0.92	0.12	0.34	RNCCKLESANNWRP	0.75	0.10	0.28

	Natural Gas Dryer/Oil DHW	Oil	0.92	0.12	0.34	RNCCKLESANOWRP	0.75	0.10	0.28
CEE TIER 2	Electric Dryer/Electric DHW	n/a	0.00	n/a	0.00	RNCCKLT2AEEWRP	0.00	n/a	0.00
	Electric Dryer/Propane DHW	Propane	0.58	n/a	0.58	RNCCKLT2AELWRP	0.48	n/a	0.48
	Electric Dryer/Natural Gas DHW	Natural Gas	0.58	n/a	0.58	RNCCKLT2AENWRP	0.48	n/a	0.48
	Electric Dryer/Oil DHW	Oil	0.58	n/a	0.58	RNCCKLT2AEOWRP	0.48	n/a	0.48
	Propane Dryer/Electric DHW	Propane	0.42	n/a	0.42	RNCCKLT2ALEWRP	0.34	n/a	0.34
	Propane Dryer/Propane DHW	Propane	1.00	n/a	1.00	RNCCKLT2ALLWRP	0.82	n/a	0.82
	Propane Dryer/Oil DHW	Oil	1.00	n/a	1.00	RNCCKLT2ALOWRP	0.82	n/a	0.82
	Natural Gas Dryer/Electric DHW	Natural Gas	0.42	n/a	0.42	RNCCKLT2ANEWRP	0.34	n/a	0.34
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	1.00	n/a	1.00	RNCCKLT2ANNWRP	0.82	n/a	0.82
	Natural Gas Dryer/Oil DHW	Oil	1.00	n/a	1.00	RNCCKLT2ANOWRP	0.82	n/a	0.82
CEE ADVANCED TIER	Electric Dryer/Electric DHW	n/a	0.00	n/a	0.00	RNCCKLT3AEEWRP	0.00	n/a	0.00
	Electric Dryer/Propane DHW	Propane	0.58	n/a	0.58	RNCCKLT3AELWRP	0.48	n/a	0.48
	Electric Dryer/Natural Gas DHW	Natural Gas	0.58	n/a	0.58	RNCCKLT3AENWRP	0.48	n/a	0.48
	Electric Dryer/Oil DHW	Oil	0.58	n/a	0.58	RNCCKLT3AEOWRP	0.48	n/a	0.48
	Propane Dryer/Electric DHW	Propane	0.50	n/a	0.50	RNCCKLT3ALEWRP	0.41	n/a	0.41
	Propane Dryer/Propane DHW	Propane	1.08	n/a	1.08	RNCCKLT3ALLWRP	0.89	n/a	0.89
	Propane Dryer/Oil DHW	Oil	1.08	n/a	1.08	RNCCKLT3ALOWRP	0.89	n/a	0.89
	Natural Gas Dryer/Electric DHW	Natural Gas	0.50	n/a	0.50	RNCCKLT3ANEWRP	0.41	n/a	0.41
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	1.08	n/a	1.08	RNCCKLT3ANNWRP	0.89	n/a	0.89
	Natural Gas Dryer/Oil DHW	Oil	1.08	n/a	1.08	RNCCKLT3ANOWRP	0.89	n/a	0.89

Early Replacement:

The first year savings are provided below, with a mid life adjustment to be applied after 3 years to bring the savings in line with a new replacement as provided above:

Efficiency Level	Configuration	Fuel Claimed	Single Family Early Replacement ΔMMBtu Replacing:				Multifamily In Unit Early Replacement ΔMMBtu Replacing:				Mid Life Adjustment Replacing:	
			Front	Item Code	Top	Item Code	Front	Item Code	Top	Item Code	Front	Top
ENERGY STAR	Electric Dryer/Electric DHW	n/a	0.00	EHCWESFEREE	0.00	EHCWESTEREE	0.00	MFCWESFEREE	0.00	MFCWESTEREE	n/a	n/a
	Electric Dryer/Propane DHW	Propane	0.58	EHCWESFEREL	2.48	EHCWESTEREL	0.48	MFCWESFEREL	2.04	MFCWESTEREL	-1%	0%
	Electric Dryer/Natural Gas DHW	Natural Gas	0.58	EHCWESFEREN	2.48	EHCWESTEREN	0.48	MFCWESFEREN	2.04	MFCWESTEREN	-1%	0%
	Electric Dryer/Oil DHW	Oil	0.58	EHCWESFEREO	2.48	EHCWESTEREO	0.48	MFCWESFEREO	2.04	MFCWESTEREO	-1%	0%
	Propane Dryer/Electric DHW	Propane	2.17		2.02		1.78		1.66		16%	17%
	Propane Dryer/Propane DHW	Propane	2.75		4.50		2.26		3.69		12%	8%
	Propane Dryer/Oil DHW	Oil	2.75		4.50		2.26		3.69		12%	8%
	Natural Gas Dryer/Electric DHW	Natural Gas	2.17		2.02		1.78		1.66		16%	17%
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	2.75		4.50		2.26		3.69		12%	8%
	Natural Gas Dryer/Oil DHW	Oil	2.75		4.50		2.26		3.69		12%	8%
CEE TIER 2	Electric Dryer/Electric DHW	n/a	0.00	EHCWT2FEREE	0.00	EHCWT2TEREE	0.00	MFCWT2FEREE	0.00	MFCWT2TEREE	n/a	n/a
	Electric Dryer/Propane DHW	Propane	1.16	EHCWT2FEREL	3.06	EHCWT2TEREL	0.96	MFCWT2FEREL	2.52	MFCWT2TEREL	50%	19%
	Electric Dryer/Natural Gas DHW	Natural Gas	1.16	EHCWT2FEREN	3.06	EHCWT2TEREN	0.96	MFCWT2FEREN	2.52	MFCWT2TEREN	50%	19%
	Electric Dryer/Oil DHW	Oil	1.16	EHCWT2FEREO	3.06	EHCWT2TEREO	0.96	MFCWT2FEREO	2.52	MFCWT2TEREO	50%	19%
	Propane Dryer/Electric DHW	Propane	2.25		2.09		1.85		1.72		19%	20%
	Propane Dryer/Propane DHW	Propane	3.41		5.16		2.80		4.24		29%	19%
	Propane Dryer/Oil DHW	Oil	3.41		5.16		2.80		4.24		29%	19%
	Natural Gas Dryer/Electric DHW	Natural Gas	2.25		2.09		1.85		1.72		19%	20%
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	3.41		5.16		2.80		4.24		29%	19%
	Natural Gas Dryer/Oil DHW	Oil	3.41		5.16		2.80		4.24		29%	19%
CEE ADVANCED TIER	Electric Dryer/Electric DHW	n/a	0.00	EHCWT3FEREE;	0.00	EHCWT3TEREE	0.00	MFCWT3FEREE	0.00	MFCWT3TEREE	n/a	n/a
	Electric Dryer/Propane DHW	Propane	1.17	EHCWT3FEREL	3.07	EHCWT3TEREL	0.96	MFCWT3FEREL	2.52	MFCWT3TEREL	50%	19%
	Electric Dryer/Natural Gas DHW	Natural Gas	1.17	EHCWT3FEREN	3.07	EHCWT3TEREN	0.96	MFCWT3FEREN	2.52	MFCWT3TEREN	50%	19%
	Electric Dryer/Oil DHW	Oil	1.17	EHCWT3FEREO	3.07	EHCWT3TEREO	0.96	MFCWT3FEREO	2.52	MFCWT3TEREO	50%	19%
	Propane Dryer/Electric DHW	Propane	2.33		2.17		1.91		1.79		21%	23%
	Propane Dryer/Propane DHW	Propane	3.49		5.24		2.87		4.30		31%	21%
	Propane Dryer/Oil DHW	Oil	3.49		5.24		2.87		4.30		31%	21%
	Natural Gas Dryer/Electric DHW	Natural Gas	2.33		2.17		1.91		1.79		21%	23%
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	3.49		5.24		2.87		4.30		31%	21%
	Natural Gas Dryer/Oil DHW	Oil	3.49		5.24		2.87		4.30		31%	21%

Efficiency Level	Dryer/DHW Fuel Combo	Single Family Early Replacement ΔMMBtu Unknown Type and DHW Fuel			Multi Family In Unit Early Replacement ΔMMBtu Unknown Type and DHW Fuel			Fuel Mid Life Adjustment	Item Code	
		DHW Fuel			DHW Fuel					
		NG	LP	Oil	NG	LP	Oil		Single Family	Multi Family
ENERGY STAR	Electric Dryer/Electric DHW	N/A							EHCWESAEREE	MFCWESAEREE
	Electric Dryer/Fuel DHW	0.231	0.240	0.177	0.190	0.197	0.146	0%	EHCWESAEREU	MFCWESAEREU
CEE TIER 2	Electric Dryer/Electric DHW	N/A							EHCWT2AEREE	MFCWT2AEREE
	Electric Dryer/Fuel DHW	0.438	0.455	0.337	0.360	0.374	0.277	47%	EHCWT2AEREU	MFCWT2AEREU
CEE ADVANCED TIER	Electric Dryer/Electric DHW	N/A							EHCWT3AEREE	MFCWT3AEREE
	Electric Dryer/Fuel DHW	0.440	0.456	0.338	0.361	0.375	0.278	47%	EHCWT3AEREU	MFCWT3AEREU

Efficiency Level	Configuration	Item Code	Low Income Single Family Voucher Program ΔMMBtu			Mid Life Adjustment Replacing:		
			NG	LP	Oil	NG	LP	Oil
ENERGY STAR	Front		0.39	0.48	0.12	9%	10%	-1%
	Top		0.87	0.97	0.50	4%	5%	0%
	Weighted Average	LICWESVOU	0.76	0.86	0.41	5%	6%	0%
CEE TIER 2	Front		0.55	0.65	0.23	36%	34%	50%
	Top		1.03	1.14	0.61	19%	19%	19%
	Weighted Average	LICWT2VOU	0.55	0.65	0.23	36%	34%	50%
CEE ADVANCED TIER	Front		0.56	0.66	0.23	37%	35%	50%
	Top		1.04	1.15	0.61	20%	20%	19%
	Weighted Average	LICWT3VOU	0.56	0.66	0.23	37%	35%	50%

Water Savings:

Market Opportunity:

The prescriptive water savings for each efficiency level are presented below:

Efficiency Level	Efficient Products & RNC ΔWater (CCF per year)			Multifamily New Construction ΔWater (CCF per year)		
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading	Weighted Average
ENERGY STAR	2.8	0.8	1.3	2.4	0.8	1.2
CEE TIER 2	2.8	n/a	2.8	2.4	n/a	2.4
CEE ADVANCED TIER	3.2	n/a	3.2	2.7	n/a	2.7

Early Replacement:

The weighted average savings are provided below, based on weighting the first year savings for 3 years and the reduced savings for the remaining 11 years. Note the screening tool currently does not allow mid life adjustments to be applied to water savings.

Efficiency Level	Single Family Early Replacement ΔWater (CCF per year) Weighted Average for Screening Replacing:			Multifamily Early Replacement ΔWater (CCF per year) Weighted Average for Screening Replacing:		
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading	Weighted Average
ENERGY STAR	5.7	4.1	4.5	4.8	3.5	3.8
CEE TIER 2	6.0	6.0	6.0	5.1	5.0	5.1
CEE ADVANCED TIER	6.4	6.4	6.4	5.4	5.3	5.4

Footnotes

[1] Assume one hour per cycle.

[2] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units (based on available product from the CEC Appliance database), 8/18/2017 and consumption data from the latest Life-Cycle Cost and Payback Period Excel-based analytical tool. See "2019 Clothes Washer Analysis.xls" for the calculation.

[3] Based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[4] Based on the average clothes washer volume of all standard sized units (greater than 2.5 cu ft) that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/18/2017.

[5] Note that the baseline and efficient model may be different in different locations.

[6] Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/

[7] EVT found the average household size in MF buildings from the 2010 Census data (1.6 people, compared to 2.3 for single family) and using the values for number of loads for different household sizes (from DOE Technical Support Document U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December, 2000. Page 7-6) and the 322 used for single families we estimate the number of loads for a MF building to be 265. See '2019 Clothes Washer Analysis.xls' for calculation.

[8] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency). Therefore a factor of 0.98/0.78 (1.26) is applied.

[9] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool.

[10] Based on inflating cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool,. See '2019 Clothes Washer Analysis.xls' for details.

[11] Note that the baseline savings for all cases (Front, Top and Weighted Average) is based on the weighted average baseline IMEF (as opposed to assuming Front baseline for Front efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

[12] Note for early replacement we are assuming the baseline unit configuration is always known but are using the weighted average IMEF for the efficient case for simplicity.

Lighting Controls

Measure Number: CI-LTG-CONT b
Portfolio: EVT TRM Portfolio 2020-01
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Lighting

Update Summary

Update include:

- Updated WHF documentation and HEff assumption.
- Addition of Remote-Mounted Dual Occupancy & Daylight Sensor assumptions.

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- NEEP CI Lighting LS FINAL Report_ver 5_7-19-11
- KEMA Lighting Controls Summary of Findings
- LBNL Lighting Controls in Commercial Buildings 2012
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- Application Assessment of Bi-Level LED Parking Lot Lighting
- kroger_case_study_final[1]
- WS-CaseStudy-Walmart_OccupancySensors
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- EVT Lighting Control Assumptions_2019
- EVT Lighting WHF Research Prescriptive_2020

Description

Controls for interior & exterior lighting, including occupancy sensors and daylight sensors.

Program Type

Time of Sale / Retrofit

Downstream

Baseline Efficiencies

This TRM applies only to Prescriptive Projects, or those projects less than 10,000 Square Feet and less than 250 rebate-eligible items, by agreement with DPS. Analysis of Occupancy Sensors and Daylight Dimming on custom projects will be calculated on a custom basis using the actual site conditions including existing controls where appropriate.

High Efficiency

Controlled lighting such as occupancy sensors and daylight dimming.

Algorithms

Electric Demand Savings

$$\Delta kW = kW_{connected} \times SVG \times OTF \times ISR \times WHF_d$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = kW_{connected} \times HOURS \times SVG \times OTF \times ISR \times WHF_e$$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$$

Where:

ΔkW	=	gross customer connected load kW savings for the measure. This number represents the maximum summer kW savings – including the reduced cooling load from the more efficient lighting.
ΔkWh	=	gross customer annual kWh savings for the measure (includes the reduced cooling load from the more efficient lighting)
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
AR	=	Typical aspect ratio factor; the default value is 60%[4] and is based on the typical square footage of commercial building within 15 feet of exterior wall. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.
DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%
HEff	=	Average heating system efficiency. For prescriptive lighting assumed to be 86.8% in existing buildings.[5]
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[6]
HOURS	=	The lighting operating hours are collected from the prescriptive application form. If not available, then assume hours per year from the table titled Lighting Operating Hours by Building Type.
ISR	=	In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[1]
$kW_{connected}$	=	kW lighting load connected to control. For multi-level and perimeter switching in the Comprehensive Track the savings is applied to all interior lighting kW load.
OA	=	Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%.[7]
OTF	=	Operational Testing Factor. OTF = 1.0 for all occupancy sensors and for daylight dimming controls when the project undergoes Operational Testing or commissioning services, 0.80 for daylight dimming controls otherwise.
SVG	=	% of annual lighting energy saved by lighting control; determined on a site-specific basis or refer to table by control type
WHF_d	=	Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[2] The cooling savings are only added to the summer peak savings. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[3]. COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak.
WHF_e	=	Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[2] For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a

typical 3.5 COP refrigeration system efficiency.

Load Shapes

For Interior lighting applications, # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.

For Exterior lighting applications, #13 (Commercial Outdoor Lighting)

For refrigerated and freezer case lighting applications, # 87 (Grocery/Conv. Store Indoor Lighting) for demand and lighting energy savings and #14 (Commercial Refrigeration) for refrigeration and freezer (cooling bonus) energy savings.

12d Commercial Indoor Lighting - Blended
13a Commercial Outdoor Lighting
14a Commercial Refrigeration
15c Commercial A/C
87b Grocery/Conv. Store Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
12	Commercial Indoor Lighting - Blended	Active	48.8%	19.5%	22.2%	9.5%	46.9%	67.9%
13	Commercial Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	70.2%	3.7%
14	Commercial Refrigeration	Active	33.0%	32.6%	17.0%	17.4%	69.0%	77.2%
15	Commercial A/C	Active	18.0%	10.0%	46.0%	26.0%	0.0%	34.2%
87	Grocery/Conv. Store Indoor Lighting	Active	39.7%	26.7%	19.7%	13.9%	84.7%	90.8%

Net Savings Factors

Measures

LECOCCEX	Exterior Occupancy Sensors
LECOCCRE	Refrigerator Case Controls
LECOCCFR	Freezer Case Controls
LECOCCDL	Fixture-Mounted Dual Occupancy & Daylight Sensor
LECOCCFX	Fixture-Mounted Occupancy Sensor
LECOCCRM	Remote-Mounted Occupancy Sensor
LECDAYFX	Fixture-Mounted Daylight Sensor
LECOCCIN	Integrated Occupancy Sensor
LECOCCWS	Wall Switch Occupancy Sensor
LECDAYRM	Remote-Mounted Daylight Sensor
LECOCCID	Integrated Dual Occupancy & Daylight Sensor
LECDULRM	Remote-Mounted Dual Occupancy & Daylight Sensor

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	LECOCCEX	0.89	1.00
C&I Retro	6012CNIR	LECOCCRE	0.89	1.00
C&I Retro	6012CNIR	LECOCCFR	0.89	1.00
C&I Retro	6012CNIR	LECOCCDL	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCEX	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCRE	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCFR	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCDL	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCEX	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCRE	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCFR	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCDL	0.98	1.00
C&I Retro	6012CNIR	LECOCCFX	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCFX	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCFX	0.98	1.00
C&I Retro	6012CNIR	LECOCCRM	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCRM	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCRM	0.98	1.00
C&I Retro	6012CNIR	LECDAYFX	0.89	1.00
Cust Equip Rpl	6013CUST	LECDAYFX	0.97	1.00
Pres Equip Rpl	6013PRES	LECDAYFX	0.98	1.00
C&I Retro	6012CNIR	LECOCCIN	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCIN	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCIN	0.98	1.00
C&I Retro	6012CNIR	LECOCCWS	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCWS	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCWS	0.98	1.00
C&I Retro	6012CNIR	LECDAYRM	0.89	1.00
Cust Equip Rpl	6013CUST	LECDAYRM	0.97	1.00
Pres Equip Rpl	6013PRES	LECDAYRM	0.98	1.00
C&I Retro	6012CNIR	LECOCCID	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCID	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCID	0.98	1.00
C&I Retro	6012CNIR	LECDULRM	0.89	1.00
Cust Equip Rpl	6013CUST	LECDULRM	0.97	1.00
Pres Equip Rpl	6013PRES	LECDULRM	0.98	1.00

Lifetimes

Controls – 10 years. Analysis period is the same as the lifetime.

Measure Cost

Lighting Control Type	Incremental Cost
Wall Switch Occupancy Sensor	$55
Fixture-Mounted Occupancy Sensor	$67
Remote-Mounted Occupancy Sensor	$125
Fixture-Mounted Daylight Sensor	$50
Remote-Mounted Daylight Sensor	$65
Integrated Occupancy Sensor	$40
Integrated Dual Occupancy & Daylight Sensor	$50
Fixture-Mounted Dual Occupancy & Daylight Sensor	$100
Remote-Mounted Dual Occupancy & Daylight Sensor	$125

Refrigerator Case Occupancy Sensor	$60
Freezer Case Occupancy Sensor	$60
Exterior Occupancy Sensor	$82

See 'EVT Lighting Control Assumptions_2019.xlsx'; "Cost" sheet for more information.

O&M Cost Adjustments

N/A

Reference Tables

Lighting Control Type	Measure Code	Item Code	Location / Application		% Savings (SVG)[8]	Default Controlled Wattage[9]
Wall Switch Occupancy Sensor	LECOCCWS	CEO-WOS-ZZ-1N	Interior		24%	84
Fixture-Mounted Occupancy Sensor	LECOCCFX	CEO-FMOS-1N	Interior		24%	81
Remote-Mounted Occupancy Sensor	LECOCCRM	CEO-ROS-ZZ-1N	Interior		24%	338
Fixture-Mounted Daylight Sensor	LECDAYFX	CEO-FDAY-ZZ-1N	Interior		28%	95
Remote-Mounted Daylight Sensor	LECDAYRM	CEO-RDAY-ZZ-1N	Interior		28%	239
Integrated Occupancy Sensor for LED Interior Fixtures < 10,000 Lumens	LECOCCIN	CEO-INTGOC-A	Interior		24%	31
Integrated Occupancy Sensor for LED Interior Fixtures >= 10,000 Lumens	LECOCCIN	CEO-INTGOC-B	Interior		24%	118
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	LECOCCID	N/A *	Interior	Verified Daylight Savings	38%	31
		CEO-INTGDL-A		No Verified Daylight Savings	24%	
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	LECOCCID	N/A *	Interior	Verified Daylight Savings	38%	118
		CEO-INTGDL-B		No Verified Daylight Savings	24%	
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	LECOCCDL	N/A *	Interior	Verified Daylight Savings	38%	31
		CEO-DUALOC-3		No Verified Daylight Savings	24%	
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	LECOCCDL	N/A *	Interior	Verified Daylight Savings	38%	118
		CEO-DUALOC-2		No Verified Daylight Savings	24%	
Remote-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures	LECDULRM	N/A *	Interior	Verified Daylight Savings	38%	239
		CEO-RDUAL-ZZ-A		No Verified Daylight Savings	24%	
Refrigerator Case Occupancy Sensor	LECOCCRE	CEO-RFR-CS-1N	Case		40%	92
Freezer Case Occupancy Sensor	LECOCCFR	CEO-FRZ-CS-1N	Case		40%	90
Exterior Occupancy Sensor	LECOCCEX	CEO-EXT-OS-1N	Exterior		41%	86

* Note all Prescriptive measures will assume no verified daylighting savings, so only custom measures where daylighting is verified will claim the higher savings value.

Lighting Operating Hours by Building Type

Building Type	Annual Hours
Grocery/Convenience Store	6,019
Hospital	4,007
K-12 Schools	2,456
Lodging/Hospitality	4,808
Manufacturing	4,781
Office	3,642
Public Assembly	3,035
Public Safety	3,116
Religious	2,648
Restaurant	4,089
Retail	4,103
Service	3,521
University/College	3,416
Warehouse	4,009
Exterior	3,338

From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf. Exterior Lighting hours based on estimated mix of photocell-controlled lighting (12 hpd) and switch-controlled lighting.

Footnotes

[1] 2005 TAG agreement.

[2] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[3] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[4] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[5] Average AFUE of the HVAC heating equipment is based on the weighted average of existing commercial heating systems, as sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[6] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[7] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[8] Interior controls % savings based on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls and exterior sensors are based upon data from "Application Assessment of Bi-Level LED Parking Lot Lighting" p6.

See 'EVT Lighting Control Assumptions_2019.xlsx' for more information.

[9] Based on Efficiency Vermont data from program year 2017. See 'EVT Lighting Control Assumptions_2019.xls'; "TRM Table" sheet for details on calculations.

LED ENERGY STAR Fixtures

Measure Number: CR-LTG-LEDESF b
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Lighting

Update Summary

The measure has been updated to:

- Since EISA backstop not enacted, language updated.
- Baseline watts now based on weighted mix (from DOE forecast), with midlife adjusment now based upon replacement lamp forecast.
- Leakage rate applied to all measures now for simplicity.
- Costs and O&M impacts calculated based on weighted baseline mix.
- 3 year assumptions calculated
- Dropship program definition provided. Downlight fixture has been added to the offerings. New Item Code for low income drop ship added.

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- Rx_C&I_LED_hours
- UMPChapter21-residential-lighting-evaluation-protocol
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- ENERGY STAR Light Fixture_Ceiling Fan Calculator
- EVT Lighting WHF Research Prescriptive_2020
- 2021-2023 EVT ESTAR Fixtures Analysis

Description

An ENERGY STAR qualifying LED fixture is purchased and installed in place of an incandescent or halogen fixture. This measure is broken into three ENERGY STAR fixture types– Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights, task and under cabinet fixtures), Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures. Assumptions are provided for the following markets: Efficient Products and SMARTLIGHT.

Market	Description
Efficient Products (Residential and Commercial)	This is for retail sales for Residential or Commercial customers.
SMARTLIGHT (Residential and Commercial)	In reference to PIP #67a: Upstream Distributor Incentive Model, Efficiency Vermont offers "upstream" incentives to Vermont Electrical Distributors for certain eligible LED fixtures.
Dropship (Residential and Commercial)	Product (a downlight fixture) is ordered via the EVT website by building owners, weatherization contractors or EVT staff. A distributor ships the products to the customer, free of charge. The building owner must confirm that the product will be installed and EVT reserve the right to inspect at a later date.

Program Type

Calculation Type: Time of Sale

Program Delivery/Implementation Type: Midstream / Downstream

Baseline Efficiencies

The baseline condition is a weighted average mix of baseline LED, CFL, Halogen and Incandescent as provided by DOE Lighting Forecast.

Efficient Equipment

High efficiency is an ENERGY STAR-qualified LED fixture meeting the requirements in Version 2.1 of the ENERGY STAR Specification for Solid State Luminaires.

Algorithms

Electric Demand Savings

ΔkW	$= ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d \times (1 - LR)$

Symbol Table

Electric Energy Savings

ΔkWh	$= ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e \times (1 - LR)$

Symbol Table

Heating Increased Usage

$\Delta MMBTU_{WH}$	$= (\Delta kWh / WHF_e) \times 0.003412 \times (1 - OA) \times AR \times HF \times DFH / \eta Heat$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure.
ΔkWh	=	Gross customer annual kWh savings for the measure.
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
$\eta Heat$	=	Average heating system efficiency = 86.8%[9]
0.003412	=	Conversion from kWh to MMBTU
AR	=	Aspect ratio factor; the typical square footage of commercial buildings within 15 feet of exterior wall. The default value is 60%.[10]
DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, .[11] Assumed to be 0.0 for residential lighting and Commercial Outdoor Fixtures.
HOURS	=	Average hours of use per year.

Fixture Type	Average Annual Hours of Use

	Residential	Commercial[6]
Indoor Fixtures	977[7]	3,666
Outdoor Fixtures	2,044[8]	3,960
Downlight Fixtures	986[7]	3,523

ISR = In service rate or the percentage of units rebated that actually get used

= 95%[1]

LR = Leakage Rate to account for bulbs sold to customers outside of the program area

= 0.015[2]

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[12]

$Watts_{BASE}$ = Baseline connected kW[3]

Program Type	Fixture Type	Baseline Watts		
		2021	2022	2023
Efficient Products, SMARTLIGHT and Dropship Residential	Indoor Fixtures	57.7	55.2	52.8
	Outdoor Fixtures	46.9	45.2	43.6
	Downlight Fixtures	51.5	49.2	46.9
Efficient Products, SMARTLIGHT and Dropship Commercial	Indoor Fixtures	37.0	36.1	35.3
	Outdoor Fixtures	32.7	32.1	31.4
	Downlight Fixtures	30.4	30.2	30.0

$Watts_{EE}$ = Energy efficient connected kW

Fixture Type	ESTAR LED (Watts)[4]
Indoor Fixtures	22.2
Outdoor Fixtures	17.9
Downlight Fixtures	19

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting, depending on market and fixture type.

Market	WHF_d
Residential	1.0
Commercial (except Outdoor Fixtures) [5]	1.102
Commercial Outdoor Fixtures	1.0

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting, depending on market and fixture type.

Market	WHF_e
Residential	1.0
Commercial (except Outdoor Fixtures) [5]	1.036
Commercial Outdoor Fixtures	1.0

Using the defaults above, the kW, kWh and MMBtu savings for each fixture type and market are provided below (see "2021-2023 ESTAR Fixture Analysis.xls" for calculation details):

Program Type	Fixture Type	2021					2022					2023					Item Codes
		ΔkW	ΔkWh	ΔMMBtu	Year of Adj	Adj	ΔkW	ΔkWh	ΔMMBtu	Year of Adj	Adj	ΔkW	ΔkWh	ΔMMBtu	Year of Adj	Adj	
Efficient Products, SMARTLIGHT and Dropship Residential	Indoor Fixtures	0.0332	32.4	0	2024	0.63	0.0309	30.2	0	2025	0.6	0.0286	27.9	0	2026	0.65	EPR-SSL-IFIX-23W RES-UPLEDFXT1
	Outdoor Fixtures	0.0271	55.5	0	2024	0.59	0.0256	52.3	0	2025	0.56	0.0240	49.1	0	2026	0.61	EPR-SSL-IFIX-17W RES-UPLEDFXT3
	Downlight Fixtures	0.0305	30.0	0	2024	0.71	0.0283	27.9	0	2025	0.69	0.0261	25.8	0	2026	0.73	EPLBLLEDRE RES-UPLEDFXT4 DSLBLLEDRE DSLBLLEDRELI
Efficient Products, SMARTLIGHT and Dropship Commercial	Indoor Fixtures	0.0153	52.6	0.0330	2024	0.63	0.0144	49.5	0.0310	2025	0.6	0.0135	46.5	0.0290	2026	0.65	EPC-SSL-IFIX-23W BES-UPLEDFXT5
	Outdoor Fixtures	0.0152	54.8	0	2024	0.59	0.0146	50.3	0	2025	0.56	0.0140	48.1	0	2026	0.61	EPC-SSL-IFIX-17W BES-UPLEDFXT7
	Downlight Fixtures	0.0117	38.8	0.0250	2024	0.71	0.0116	39.8	0.0250	2025	0.69	0.0114	39.2	0.0250	2026	0.73	EPLBLLEDCO BES-UPLEDFXT8 DSLBLLEDCO DSLBLLEDCOLI

Baseline Adjustment

The natural growth of LED market share, has and will continue to grow over the lifetime of the LED measures installed. Therefore a forecast of the baseline growth of LED lamps has been developed, based upon historical growth rates provided via CREED LightTracker data for no-program states, and review of projections provided by the Department of Energy.

This forecast is used to estimate how baseline replacement lamps would change over the lifetime of the LED fixture. A single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. The appropriate adjustments as a percentage of the base year savings for each fixture type are provided in the table above

Load Shapes

Market	Fixture Type	Loadshape
Residential	Indoor Fixtures	Residential Indoor Lighting
	Downlight Fixtures	
	Outdoor Fixtures	Residential Outdoor Lighting
Commercial	Indoor Fixtures	Commercial EP Lighting with cooling bonus
	Downlight Fixtures	

	Outdoor Fixtures	Commercial Outdoor Lighting

1a Residential Indoor Lighting
2a Residential Outdoor Lighting
13a Commercial Outdoor Lighting
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9%	35.0%	13.0%	15.1%	29.8%	8.2%
2	Residential Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	34.6%	1.8%
13	Commercial Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	70.2%	3.7%
101	Commercial EP Lighting with cooling bonus	Active	47.7%	19.2%	23.0%	10.1%	33.8%	68.1%

Net Savings Factors

Measures

LFHRDLED	LED Recessed Surface or Pendant Downlight
LFHLEDOU	LED Outdoor Fixture
LFHLEDIN	LED Indoor Fixture

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032EPEP [is base track]	Efficient Products - Residential
6032UPST [6032EPEP]	Upstream - Residential
6013EPEP [6032EPEP]	Efficient Products - Commercial

Lifetimes

Lifetime is a function of the rated life[13] and average hours of use of the luminaire[14]

Fixture Type	Rated Life (Hours)	Lifetime (Years)	
		Residential	Commercial
Indoor Fixtures	48,000	15.0	13.1
Outdoor Fixtures	48,000	15.0	12.1
Downlight Fixtures	49,000	15.0	13.9

Persistence

The persistence factor is assumed to be one.

Measure Cost

The incremental cost for this measure is dependent on the baseline mix and provided in the table below.[15]

		Fixture Incremental Cost		
		2021	2022	2023
Residential	Indoor Fixtures	$13	$12	$11
	Outdoor Fixtures	$14	$13	$13
	Downlight Fixtures	$7	$7	$6
Commercial	Indoor Fixtures	$7	$6	$6
	Outdoor Fixtures	$8	$8	$7
	Downlight Fixtures	$3	$3	$3

For the Dropship program (only Downlight fixtures) - the full LED cost is used of $24.

O&M Cost Adjustments

To account for the shift in baseline due to replacement lamps, the levelized baseline replacement cost over the lifetime of the LED is calculated. The key assumptions used in this calculation are documented below.

	Replacement Lamp Costs		Assumed Lifetime (hours)
	Omnidirectional	Directional	
LED	$5.00	$10.00	
CFL	$2.50	$4.50	10,000
Halogen	$1.25	$3.50	1,000
Incandescent	$0.50	$3.50	1,000

The calculation results in the following assumptions of equivalent annual baseline replacement cost (see "2021-2023 ESTAR Fixture Analysis.xls" for calculation details)

		Annual O&M Cost		
		2021	2022	2023
Residential	Indoor Fixtures	$0.25	$0.23	$0.21
	Outdoor Fixtures	$0.36	$0.33	$0.30
	Downlight Fixtures	$1.08	$0.96	$0.84
Commercial	Indoor Fixtures	$0.11	$0.09	$0.07
	Outdoor Fixtures	$0.11	$0.09	$0.07
	Downlight Fixtures	$0.09	$0.07	$0.07

Footnotes

[1] Efficiency Vermont removes savings claims for lamps that have been returned. The 95% ISR assumes that 5% of fixtures are never installed. EVT plan to review this assumption for future iterations.

[2] A leakage rate of 1.5% was agreed to by EVT and DPS during October 2017 TAG. This value is an estimate based on leakage rates used by other programs, geographic factors, and a consideration of similar lighting programs in surrounding service territories.

[3] Weighted average baseline wats based on US Deparment of Energy, "Energy Savings Forecast of Solid State Lighting in General Illumination Applications", December 2019. See "2021-2023 ESTAR Fixture Analysis.xls" for calculation details

[4] Based on average of the ESTAR fixtures on the QPL accessed 10/2020. See file "2021-2023 ESTAR Fixture Analysis.xls" for calculation details.

[5] The default waste heat factors for demand and energy for commercial indoor fixtures are from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[6] Commercial hours based on 3-year weighted average for fixtures rebated through Efficiency Vermont's Business Energy Services prescriptive program, through 12/14/2015. See Rx_C&I_LED_hours.xlsx for analysis

[7] Based on weighted average of Residetial Indoor: household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1, and Residential Task/Under Cabinet: Estimated at 2 hours per day.

[8] Based on a household exterior average 5.6 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[9] Average AFUE of the HVAC heating equipment is based on the weighted average of existing commercial heating systems, as sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[10] The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page

v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[11] From "Calculating lighting and HVAC Interactions", Table 1, ASHRAE Journal November 1993. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[12] 2017 ASHRAE Handbook Fundamentals (p. 16.3): "Conventional all-air air-handling systems for commercial and institutional buildings often have approximately 10 to 40% outside air." For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[13] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 10/2020.

[14] Lifetimes are capped at 15 years even when the rated life/hours of use are higher.

[15] LED costs are based on program data. See "2021-2023 ESTAR Fixture Analysis.xls" for calculation details.

LED Other Fixtures

Measure Number: CR-LTG-LEDOF c
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Lighting

Update Summary

This update includes:

- Updating the efficient wattage based on DLC listed fixtures meeting the new 5.0 standard.

Referenced Documents

- 2009 ASHRAE Handbook Fundamentals
- Calculating Lighting and HVAC Interactions_ASHRAE
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- DNVGL_MA CI Upstream Lighting In-Storage Lamps Follow-up Study_Mar 2015
- EVT Lighting WHF Research Prescriptive_2020
- EVT_LED Other Fixtures_Analysis 2021
- LED Other Fixtures_DLC Average_2021

Description

The measures included in this TRM are LED lighting technologies intended for installation on retrofit, market opportunity, and new construction projects. LED lighting systems have source efficacies (lumens per watt) that can match or exceed efficacies of incandescent, compact fluorescent, linear fluorescent and HID lighting. In addition, LED's inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. Eligible measures include new fixtures and retrofit kits. Measures may be offered through the commercial lighting standard rebate form or through the efficiencyvermont.com on-line rebate application (C&I Rebate Form), or under the SMARTLIGHT program ("midstream" incentives to Vermont electrical distributors) or through the custom Multifamily programs. The current offering of fixture technologies and programs are provided below but are subject to change and the attached analysis file provides savings results for any combination of fixture, program and control.

Program Type

Calculation Type: Time of Sale

Program Delivery/Implementation Type: Midstream / Downstream

Baseline Efficiencies

All measures assume a market opportunity baseline fixture with equivalent lumens (Standard T8, T5, Metal Halide, CFL or Incandescent dependent on fixture type) as provided in Reference Tables below[1].

The baseline in Multifamily New Construction programs incorporates the 2015 Vermont RBES requirement that 75% of fixtures have high efficacy lamps. The baseline is made up of 75% high efficacy as defined by the RBES and consistent with the C&I baseline, and 25% baseline EISA-qualified wattages that produce similar lumen output. The 2020 Vermont RBES requirement that 90% of fixtures have high efficacy lamps will be assumed as baseline from 2022.

High Efficiency

Eligible LED products include LED case fixtures, LED Linear/Troffer fixtures, LED Low and High Bay fixtures and LED exterior fixtures, grouped in to lumen bins as provided in Reference Tables below..

All fixtures must be listed on the DesignLights Consortium Qualified Products List.

Algorithms

Electric Demand Savings

$\Delta kW = ((Watts_{BASE} - (Watts_{EE} \times (1 - Control\%Savings))) / 1000) \times ISR \times WHF_d$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((Watts_{BASE} - (Watts_{EE} \times (1 - Control\%Savings))) / 1000) \times HOURS \times ISR \times WHF_e$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003412 \times (1 - OA) \times AR \times HF \times DFH / \eta Heat$

Symbol Table

Waste Heat Adjustment

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF).

Where:

ΔkW	=	Gross customer connected load kW savings for the measure
ΔkWh	=	Gross customer annual kWh savings for the measure
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
ηHeat	=	Average heating system efficiency, For prescriptive lighting, assumed to be 86.8% in existing buildings[12]
0.003412	=	Conversion from kWh to MMBTU
AR	=	Aspect ratio factor; the typical square footage of commercial buildings within 15 feet of exterior wall. The default value is 60%.[13]
Control%Savings	=	Percent savings for fixtures with integrated controls

Fixtures without Integrated Controls	0%
Fixtures with Integrated Occupancy Sensor Controls	24%
Fixtures with Integrated Dual Occupancy & Daylight Sensor Controls with Verified Daylight savings	38%
Fixtures with Integrated Dual Occupancy & Daylight Sensor Controls without Verified Daylight savings	24%
Prescriptive Fixtures with Integrated Controls	24%

DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95% except agriculture, refrigerated case and exterior fixtures which are assumed to be 0%.
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting. [14]

Assumed to be 0.0 for multifamily and residential lighting.

HOURS = Annual lighting hours of use per year. Assumptions are dependent on implementation, fixture type, customer and/or location:

Implementation	Customer or Location Type	LED Category	Operating Hours
C&I Rebate Form	C&I	Collected from prescriptive form	
Smartlight	Residential	All Interior Fixtures	986[5]
		All Exterior Fixtures	2044[6]
	C&I[7]	LED Case Fixtures	5950
		LED Linear / Troffers	3458
		LED High & Low Bay Fixtures	3325
		LED Exterior Fixtures	3789
Multifamily	In-unit	All Fixtures	1204.5[8]
	Indoor Hallway / Stairway or Corridor		8760
	Laundry and other Common Areas		4380[9]
	Exterior Tenant Controlled		2007.5[10]
	Exterior Master Controlled		3960[11]

ISR = In service rate, or the percentage of units rebated that actually get used. For all categories of fixtures, the ISR is 95%[2].

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[15]

$Watts_{BASE}$ = Baseline connected wattage from table located in Reference Tables section.

$Watts_{EE}$ = Energy efficient connected wattage from table located in Reference Tables section.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting, depending on market and fixture type.

Market	WHF_d
Residential and Multifamily	1.0
Commercial (except Exterior and Refrigerated Case Fixtures) [3]	1.102
Refrigerated Case Fixtures [4]	1.29
Commercial Exterior Fixtures	1.0

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting, depending on market and fixture type.

Market	WHF_e
Residential and Multifamily	1.0
Commercial (except Exterior and Refrigerated Case Fixtures) [3]	1.036
Refrigerated Case Fixtures [4]	1.29
Commercial Exterior Fixtures	1.0

Midlife Baseline Adjustment

The Multifamily blended baseline assumption includes 25% EISA compliant halogen bulb. To account for shifting baselines it is assumed that the savings become 100% of the T8 or CFL baseline from 2023. Therefore a midlife baseline adjustment as provided below will be applied in 2023:

LED Category	LED Measure Description	Midlife Adjustment in 2023
LED Linear / Troffers	LED Linear / Troffers, <=3000 lumens	26%
	LED Linear / Troffers, 3001-4500 lumens	41%
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	70%
	LED Exterior Fixtures, 2,001-5,000 lumens	64%

Load Shapes

For C&I Rebate Form interior lighting use # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and where C&I cooling savings are characterized, use #15 (Commercial A/C) cooling energy savings.

For exterior lighting C&I applications; #13 (Commercial Outdoor Lighting)

For Residential or in-unit multifamily applications; #1 (Residential Indoor Lighting).

For multifamily common area fixtures applications; #12 (Commercial Indoor Lighting-Blended).

For multifamily hallway / stairway or corridor: #25 Flat (8760 hours)

For C&I Smartlight; #101 (Commercial EP Lighting with Cooling Bonus) [16]

For C&I Smartlight refrigerated and freezer case lighting applications, # 87 (Grocery/Conv. Store Indoor Lighting)

For C&I Rebate Form refrigerated and freezer case lighting applications, # 87 (Grocery/Conv. Store Indoor Lighting) for demand and lighting energy savings and #14 (Commercial Refrigeration) for refrigeration and freezer (cooling bonus) energy savings.

1a Residential Indoor Lighting
2a Residential Outdoor Lighting
12d Commercial Indoor Lighting - Blended
13a Commercial Outdoor Lighting
14a Commercial Refrigeration
15c Commercial A/C
87b Grocery/Conv. Store Indoor Lighting
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9%	35.0%	13.0%	15.1%	29.8%	8.2%
2	Residential Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	34.6%	1.8%
12	Commercial Indoor Lighting - Blended	Active	48.8%	19.5%	22.2%	9.5%	46.9%	67.9%
13	Commercial Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	70.2%	3.7%
14	Commercial Refrigeration	Active	33.0%	32.6%	17.0%	17.4%	69.0%	77.2%
15	Commercial A/C	Active	18.0%	10.0%	46.0%	26.0%	0.0%	34.2%
87	Grocery/Conv. Store Indoor Lighting	Active	39.7%	26.7%	19.7%	13.9%	84.7%	90.8%
101	Commercial EP Lighting with cooling bonus	Active	47.7%	19.2%	23.0%	10.1%	33.8%	68.1%

Net Savings Factors

Measures

LFHRCLED	LED Refrigerated Case Lighting
LFHHBLED	LED High- and Low-Bay Fixtures
LFHEXLED	LED Exterior Fixtures
LBLHDLED	LED HID Lamp Replacement-Type B/C (direct-wired)
LFHLEDEX	LED Exterior DLC Fixtures SMARTLIGHT
LFHLEDHB	LED High- and Low-Bay Fixtures SMARTLIGHT
LFHLEDRC	LED Refrigerated Case Lighting SMARTLIGHT
LFHLTLED	LED Linear and Troffer Fixtures
LFHLEDLT	LED Linear and Troffer Fixtures SMARTLIGHT

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6013UPST [is base track]	Upstream - Commercial
6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6017CUST [is base track]	6017CUST
6020CUST [is base track]	6020CUST
6032UPST [6032EPEP]	Upstream - Residential

Lifetimes

Estimated as the rated lifetime (50,000 hours as required by DLC) divided by annual operating hours. Measure lifetime is capped at 15 years.

Analysis period is the same as lifetime.

Measure Cost

All measure costs are assumed to be incremental costs vs. the market opportunity baselines. LED costs are based on recent Efficiency Vermont experience and cost estimates provided by the U.S. Department of Energy[17]. Refer to Reference Tables section of this document for incremental measure cost data.

For Integrated Controls, in addtion to the Fixture cost provided below a Control adder is applied (consistent with Lighting Controls assumptions)[18]:

Lighting Control Type	Incremental Cost Adder
Integrated Occupancy Sensor	$40
Integrated Dual Occupancy & Daylight Sensor	$50
Prescriptive Fixture with Integrated Control	$45

O&M Cost Adjustments

See worksheet "Rx Table" within the reference file EVT_LED Other Fixtures_Analysis_2021.xlsx for details.

LED New and Baseline Assumptions									
LED Category	**LED Measure Description**	**LED Lamp Life (hrs)**	**LED Lamp Replacement Cost**	**LED Driver Life (hrs)**	**LED Driver Replacement Cost**	**Baseline Lamp Life (hrs)**	**Baseline Lamp Replacement Cost Combined**	**Baseline Ballast Life (hrs)**	**Baseline Ballast Replacement Cost Combined**
LED Case Fixtures	LED Refrigerated Case Light, Horizontal or Vertical, <= 1700 lumens	50,000	$40.52	70,000	$40.00	24,000	$6.17	40,000	$31.00
	LED Refrigerated Case Light, Horizontal or Vertical, > 1700 lumens	50,000	$64.51	70,000	$40.00	18,000	$13.17	40,000	$56.00
LED Linear / Troffers	LED Linear / Troffers, <=4,500 lumens	50,000	$88.37	70,000	$40.00	24,000	$21.20	40,000	$35.00
	LED Linear / Troffers, >4,500 lumens	50,000	$117.13	70,000	$40.00	24,000	$19.41	40,000	$36.08
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	50,000	$113.51	70,000	$62.50	18,000	$64.50	40,000	$92.50
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	$185.39	70,000	$62.50	18,000	$86.00	40,000	$92.50
	LED High-Bay Fixtures, >15,000 lumens	50,000	$267.24	70,000	$62.50	18,000	$147.50	40,000	$128.26
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	50,000	$66.72	70,000	$62.50	13,292	$30.19	40,000	$72.61
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$124.05	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, >10,000 lumens	50,000	$266.02	70,000	$62.50	15,000	$70.33	40,000	$127.15

Reference Tables

See worksheet "Rx TABLE" within the reference file EVT_LED Other Fixtures_Analysis_2021.xlsx for details. Calculation of average DLC 5.0 Standard LED wattage for each category is provided in "LED Other Fixtures_DLC Average_2021"

LED New and Baseline Assumptions										
LED Category	LED Measure Description	WattsEE (DLC Blended)	Baseline Description	WattsBASE	Delta Watts (DLC Blended)	EE Cost	Baseline Cost	Incremental Cost	Rx Measure Code	Smartlight Measure Code
LED Case Fixtures	LED Refrigerated Case Light, Horizontal or Vertical, <= 1700 lumens	10.1	T8 1L-F32 w/ Elec - 4'	32.0	21.9	$57.21	$20	$37 $77 with Integrated Occupancy Sensor	LFHRCLED	LFHLEDRC
	LED Refrigerated Case Light, Horizontal or Vertical, > 1700 lumens	26.4	T5HO 1L-F54T5HO - 4'	59.0	32.6	$67.87	$30	$38 $78 with Integrated Occupancy Sensor	LFHRCLED	LFHLEDRC
								$53		

LED Linear / Troffers	LED Linear / Troffers, <=4500 lumens	29.5	Weighted Mix	64.7	35.2	$105.08	$52.41	$93 with Integrated Occupancy Sensor $103 with Integrated Dual Sensor $98 with Rx Integrated Control	LFHLTLED	LFHLEDLT
	LED Linear / Troffers, >4500 lumens	43.7	Weighted Mix	91.9	48.2	$134.58	$57.61	$77 $117 with Integrated Occupancy Sensor $127 with Integrated Dual Sensor $122 with Rx Integrated Control	LFHLTLED	LFHLEDLT
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	52.9	T8HO 3L-F48/HO Low-Bay	157.0	104.1	$148.16	$75	$73 $113 with Integrated Occupancy Sensor $123 with Integrated Dual Sensor $118 with Rx Integrated Control	LFHHBLED	LFHLEDHB
	LED High-Bay Fixtures, 10,001-15,000 lumens	95.8	T8HO 4L-F48/HO High-Bay	196.0	100.2	$223.54	$100	$124 $164 with Integrated Occupancy Sensor $174 with Integrated Dual Sensor $169 with Rx Integrated Control	LFHHBLED	LFHLEDHB
	LED High-Bay Fixtures, >15,000 lumens	172.1	Weighted Mix	336.2	164.1	$339.94	$135.76	$204 $244 with Integrated Occupancy Sensor $254 with Integrated Dual Sensor $249 with Rx Integrated Control	LFHHBLED	LFHLEDHB
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	21.0	Weighted Mix	75.7	54.6	$165.75	$42.92	$123 $163 with Integrated Occupancy Sensor $173 with Integrated Dual Sensor $168 with Rx Integrated Control	LFHEXLED	LFHLEDEX
	LED Exterior Fixtures, 5,001-10,000 lumens	61.7	175W Pulse Start Metal Halide	198.9	137.2	$336.39	$90	$246 $286 with Integrated Occupancy Sensor $296 with Integrated Dual Sensor $291 with Rx Integrated Control	LFHEXLED	LFHLEDEX
	LED Exterior Fixtures, > 10,000 lumens	178.2	Weighted Mix	363.4	185.2	$509.76	$133.96	$376 $416 with Integrated Occupancy Sensor $426 with Integrated Dual Sensor $421 with Rx Integrated Control	LFHEXLED	LFHLEDEX

Multi Family Fixtures:

LED Category	LED Measure Description	WattsEE (DLC Blended)	WattsEE (DLC Standard)	WattsEE (DLC Premium)	Baseline Description	WattsBASE	Delta Watts (DLC Blended)	Delta Watts (DLC Standard)	Delta Watts (DLC Premium)	Incremental Cost	Measure Code
LED Linear / Troffers	LED Linear / Troffers, <=3000 lumens	20.7	21.1	20.2	MF: (0.75 * T8 U-Tube 1L-FB32 w/ Elec - 2') + (0.25 * 3 * 53W halogens)	63.8	43.0	42.6	43.5	$46 $86 with Integrated Occupancy Sensor $96 with Integrated Dual Sensor $91 with Rx Integrated Control	LFHLTLED
	LED Linear / Troffers, 3001-4500 lumens	32.1	34.6	29.9	MF: (0.75 * T8 2L-F32 w/ Elec - 4') + (0.25 * 3 * 72W halogens)	98.3	66.1	63.7	68.4	$44 $84 with Integrated Occupancy Sensor $94 with Integrated Dual Sensor $89 with Rx Integrated Control	LFHLTLED
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	13.2	13.2	13.1	MF: (0.75 * 42W 4-pin CFL) + (0.25 * 2 * 53W halogens)	61.8	48.5	48.5	48.7	$85 $125 with Integrated Occupancy Sensor $135 with Integrated Dual Sensor $130 with Rx Integrated Control	LFHEXLED
	LED Exterior Fixtures, 2,001-5,000 lumens	31.4	32.7	28.2	MF: (0.75 * 100W Metal Halide) + (0.25 * 2 * 150W halogens)	160.2	128.8	127.5	132.0	$111 $151 with Integrated Occupancy Sensor $161 with Integrated Dual Sensor $156 with Rx Integrated Control	LFHEXLED

Deemed savings are provided below:

NO INTEGRATED CONTROLS

		C&I Rebate Form	Smartlight C&I				Smartlight RES			
LED New and Baseline Assumptions		Itemcode	ΔkWh	ΔkW	ΔMMBtu	Itemcode	ΔkWh	ΔkW	ΔMMBtu	Itemcode
LED Category	LED Measure Description	Savings dept on hours								
LED Case Fixtures	LED Refrigerated Case Light, Horizontal or Vertical, <= 1700 lumens	BES-LED-RFR11	159.9	0.0269	0.0000	BES-UPLED-RF11				
	LED Refrigerated Case Light, Horizontal or Vertical, > 1700 lumens	BES-LED-RFR12	238.1	0.0400	0.0000	BES-UPLED-RF12				
LED Linear / Troffers	LED Linear / Troffers, <=4500 lumens	BES-LED-LT-A	119.9	0.0369	0.0759	BES-UPLED-LT-A	33.0	0.0335	0.0000	RES-UPLED-LT-A
	LED Linear / Troffers, >4500 lumens	BES-LED-LT-B	163.9	0.0504	0.1037	BES-UPLED-LT-B	45.1	0.0458	0.0000	RES-UPLED-LT-B
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	BES-LED-LB-A	340.5	0.1089	0.2154	BES-UPLED-LB-A	97.5	0.0989	0.0000	RES-UPLED-LB-A
	LED High-Bay Fixtures, 10,001-15,000 lumens	BES-LED-HB-A	327.9	0.1049	0.2074	BES-UPLED-HB-A	93.9	0.0952	0.0000	RES-UPLED-HB-A
	LED High-Bay Fixtures, >15,000 lumens	BES-LED-HB-D	537.1	0.1718	0.3398	BES-UPLED-HB-D	153.7	0.1559	0.0000	RES-UPLED-HB-D
	LED Exterior Fixtures, <= 5,000 lumens	BES-XTR-A	196.7	0.0519	0.0000	BES-UPLED-XTR-A	106.1	0.0519	0.0000	RES-UPLED-XTR-A
						BES-				RES-

LED Category	LED Measure Description	C&I Rx Itemcode	Smartlight C&I ΔkWh	ΔkW	ΔMMBtu	Itemcode	Smartlight RES ΔkWh	ΔkW	ΔMMBtu	Itemcode
LED Exterior Fixtures	LED Exterior Fixtures, 5,001-10,000 lumens	BES-XTR-B	493.9	0.1303	0.0000	BES-UPLED-XTR-B	266.4	0.1303	0.0000	RES-UPLED-XTR-B
	LED Exterior Fixtures, > 10,000 lumens	BES-XTR-G	666.8	0.1760	0.0000	BES-UPLED-XTR-G	359.7	0.1760	0.0000	RES-UPLED-XTR-G

WITH INTEGRATED CONTROLS

		C&I Rx	Smartlight C&I				Smartlight RES			
LED New and Baseline Assumptions		Itemcode	ΔkWh	ΔkW	ΔMMBtu	Itemcode	ΔkWh	ΔkW	ΔMMBtu	Itemcode
LED Category	LED Measure Description	Savings dept on hours								
LED Case Fixtures	LED Refrigerated Case Light, Horizontal or Vertical, <= 1700 lumens	BES-LED-RFR11IC	177.5	0.0298	0.0000	BES-UPLED-RF11IC				
	LED Refrigerated Case Light, Horizontal or Vertical, > 1700 lumens	BES-LED-RFR12IC	284.2	0.0478	0.0000	BES-UPLED-RF12IC				
LED Linear / Troffers	LED Linear / Troffers, <=4500 lumens	BES-LED-LT-AIC	144.0	0.0443	0.0911	BES-UPLED-LT-AIC	39.6	0.0402	0.0000	RES-UPLED-LT-AIC
	LED Linear / Troffers, >4500 lumens	BES-LED-LT-BIC	199.6	0.0614	0.1263	BES-UPLED-LT-BIC	54.9	0.0557	0.0000	RES-UPLED-LT-BIC
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	BES-LED-LB-AIC	382.1	0.1222	0.2417	BES-UPLED-LB-AIC	109.4	0.1109	0.0000	RES-UPLED-LB-AIC
	LED High-Bay Fixtures, 10,001-15,000 lumens	BES-LED-HB-AIC	403.1	0.1290	0.2550	BES-UPLED-HB-AIC	115.4	0.1170	0.0000	RES-UPLED-HB-AIC
	LED High-Bay Fixtures, >15,000 lumens	BES-LED-HB-DIC	672.3	0.2151	0.4253	BES-UPLED-HB-DIC	192.4	0.1952	0.0000	RES-UPLED-HB-DIC
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	BES-XTR-AIC	214.8	0.0567	0.0000	BES-UPLED-XTR-AC	115.9	0.0567	0.0000	RES-UPLED-XTR-AC
	LED Exterior Fixtures, 5,001-10,000 lumens	BES-XTR-BIC	547.2	0.1444	0.0000	BES-UPLED-XTR-BC	295.2	0.1444	0.0000	RES-UPLED-XTR-BC
	LED Exterior Fixtures, > 10,000 lumens	BES-XTR-GIC	820.7	0.2166	0.0000	BES-UPLED-XTR-GC	442.7	0.2166	0.0000	RES-UPLED-XTR-GC

Deemed MF savings are provided below:

		Multifamily - In unit			Multifamily - Indoor Hallway / Stairway or Corridor			Multifamily - Laundry and other Common Areas		
LED Category	LED Measure Description	ΔkWh	ΔkW	ΔMMBtu	ΔkWh	ΔkW	ΔMMBtu	ΔkWh	ΔkW	ΔMMBtu
LED Linear / Troffers	LED Linear / Troffers, <=3000 lumens	27.4	0.0228	0.0000	199.5	0.0228	0.0000	99.8	0.0228	0.0000
	LED Linear / Troffers, 3001-4500 lumens	48.7	0.0405	0.0000	354.4	0.0405	0.0000	177.2	0.0405	0.0000

		Multifamily - Exterior Tenant Controlled			Multifamily - Exterior Master Controlled		
LED Category	LED Measure Description	ΔkWh	ΔkW	ΔMMBtu	ΔkWh	ΔkW	ΔMMBtu
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	75.7	0.0377	0.0000	149.3	0.0377	0.0000
	LED Exterior Fixtures, 2,001-5,000 lumens	192.3	0.0958	0.0000	379.3	0.0958	0.0000

Footnotes

[1] See worksheet "WattsBase (Lumen Analysis)" within the reference file EVT_LED Other Fixture_Analysis_2021.xlsx for details. The following methodology was used in establishing lumen bins and baseline/LED lumen equivalency:

- Define lumen bin ranges that are consistent sizes while reasonably balancing the distribution of DLC qualified products across the bins. Regular/consistent bin increments are preferred in order to reduce confusion for both customers and EVT implementation staff.
- Define baseline technology types for each lumen bin using actual equipment and not a hypothetical calculated baseline.
- Calculate the delivered lumens for each baseline technology. [Baseline delivered lumens = lamp qty x mean lamp lumens x ballast factor x fixture efficiency].
- Calculate the LED initial lumen output that would be equivalent to the baseline. Note that LED fixtures have no ballast factor and fixture efficiency is not applicable due to absolute photometry. [LED initial lumens = baseline delivered lumens / LED lumen maintenance]. Every attempt will be made to reasonably center the LED lumen output within a lumen bin, however the goals of consistent bin increments and baselines made up of actual equipment will result in some LED lumen values being uncentered within a lumen bin.

[2] Efficiency Vermont removes savings claims for lamps that have been returned. The 95% ISR assumes that 5% of fixtures are never installed. EVT plan to review this assumption for future iterations.

[3] The default waste heat factors for demand and energy for commercial indoor fixtures are from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[4] Calculated as (1 + (1.0 / 3.5)). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5 COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak. Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[5] Operating hours for all Residential LED Fixtures are based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[6] Based on a household exterior average 5.6 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[7] Operating hours for Commercial LED Fixtures are based on Efficiency Vermont data for prescriptive applications from 2016 through May 2019. See "EVTLightingHours16-19.xls"

[8] Based on average daily hours of use of 3.3, from Table 3-5, page 43, value for Living Space for Upstate New York, from NMR Group, Inc., Northeast Residential Lighting Hours-of-Use Study.

[9] Assumes 12 hours per day.

[10] Based on average daily hours of use of 5.5 exterior, from Table 3-1, page 34 for Upstate New York from NMR Group, Inc., Northeast Residential Lighting Hours-of-Use Study.

[11] Commercial hours based on 3-year weighted average for fixtures rebated through Efficiency Vermont's Business Energy Services prescriptive program, through 12/14/2015. See Rx_C&I_LED_hours.xlsx for analysis

[12] Average AFUE of the HVAC heating equipment is based on the weighted average of existing commercial heating systems, as sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[13] The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[14] From "Calculating lighting and HVAC Interactions", Table 1, ASHRAE Journal November 1993. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[15] 2017 ASHRAE Handbook Fundamentals (p. 16.3): "Conventional all-air air-handling systems for commercial and institutional buildings often have approximately 10 to 40% outside air." For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[16] Based on Commercial "Small" Lighting coincidence factors from KEMA; "C&I Lighting Load Shape Project Final Report," July 19, 2011, prepared for the Regional Evaluation, Measurement and Verification Form, submitted to NEEP. The winter coincidence factor has been adjusted to remove the cooling bonus from winter peak demand.

[17] See worksheet "EE Cost (EVT Program Data)" within the reference file EVT_LED Other Fixture_Analysis_2021.xlsx for details.

[18] Estimate based on 2018 Integrated Control research

LED Other Lamps

Measure Number: CR-LTG-LEDOL c
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Lighting

Update Summary

- Update efficient wattage due to DLC standard 5.0
- EP version of LED HID Replacement Lamps and Pin Base Lamps removed as these have not been and will not be offered through this program. These will continue to be available through Smartlight, collecting customer information.
- Applying leakage rate to TLEDs through EP and Smartlight to streamline measures.

Referenced Documents

- PIP #67a: Upstream Distributor Incentive Model
- Calculating Lighting and HVAC Interactions_ASHRAE
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- DNV GL_MA CI Upstream Lighting In-Storage Lamps Follow-up Study_Mar 2015
- GNV GL_MA Upstream Lighting Initiative Impact Evaluation PY2015_Nov 2017
- NREL_UMP Chapter 6 Res Lighting Protocol_Oct 2017
- EVT Lighting WHF Research Prescriptive_2020
- LED Other Lamp Analysis 2021
- DLC_112020_Other Lamps

Description

Efficiency Vermont will offer rebates for LED lamps to residential or commercial customers at particpatng retail locations. The eligible technologies are LED Linear Replacement Lamps, LED HID Replacement Lamps, and LED Pin-Base CFL Replacement Lamps. Refer to the ENERGY STAR Integrated Screw Based SSL (LED) Lamps measure for Screw Base LED Lamp savings.

Measures may be offered through the commercial lighting standard rebate form, through the efficiencyvermont.com on-line rebate application, under the SMARTLIGHT program ("midstream" incentives to Vermont electrical distributors).

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Midstream, Downstream

Baseline Efficiencies

Baseline for LED Linear Replacement Lamps (TLEDs) are the equivalent Standard T8s, for LED HID Replacement Lamps the baseline is Metal Halides and for LED Pin-Base, the baseline is pin-base CFLs.

Refer to the "Wattage Assumptions, Deemed Savings, and Measure Costs" tables in the Reference Tables section for lighting baseline efficiencies and savings.

High Efficiency

The efficient case is LED Linear Replacement Lamps (TLEDs), LED HID Replacement Lamps and LED Pin-Base lamps within various lumen ranges, meeting DLC 5.0 standards.

Refer to the "Wattage Assumptions, Deemed Savings, and Measure Costs" tables in the Reference Tables section for efficient lighting wattage and savings.

Algorithms

Electric Demand Savings

ΔkW $= ((Watts_{BASE} – Watts_{EE}) /1000) \times ISR \times WHF_d \times (1 - LR)$

Symbol Table

Electric Energy Savings

ΔkWh $= ((Watts_{BASE} – Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e \times (1 - LR)$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$\Delta MMBTU_{WH}$ $= (\Delta kWh / WHF_e) \times 0.003412 \times (1 – OA) \times AR \times HF \times DFH / \eta Heat$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure
ΔkWh	=	Gross customer annual kWh savings for the measure
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
ηHeat	=	Average heating system efficiency, For prescriptive lighting, assumed to be 86.8% in existing buildings.[11]
0.003412	=	Conversion from kWh to MMBTU
AR	=	Aspect ratio factor; the typical square footage of commercial buildings within 15 feet of exterior wall. The default value is 60%.[12]
DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting.[13] Assumed to be 0.0 for residential lighting.
HOURS	=	Annual lighting hours of use per year. See table below.

LED Category	Customer Type	Operating Hours
All	C&I Rx	Collected from prescriptive form
LED Linear Replacement	Commercial EP and Smartlight	3554[6]
	Residential EP and Smartlight	986[7]
LED HID Replacement Lamps	Commercial Smartlight	3614[8]
	Residential Smartlight	2044[9]

Pin Base Lamps	Commercial Smartlight	3100[10]
	Residential Smartlight	986[7]

ISR = In service rate, or the percentage of units rebated that actually get used. See table below.

LED Category	Customer Type	ISR
LED Linear Replacement	Commercial	0.92[1]
	Residential	0.97[2]
LED HID Replacement Lamps	Commercial	0.846[3]
	Residential	0.97[2]
Pin Base Lamps	Commercial	0.846[3]
	Residential	0.97[2]

LR = Leakage Rate to account for bulbs sold to customers outside of the program area

Lamp type	Leakage Rate
LED Linear Replacement	0.015[4]
LED HID Replacement Lamps	0
Pin Base Lamps	0

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%.[14]

$Watts_{BASE}$ = Baseline connected Watts from table located in Reference Tables Section.

$Watts_{EE}$ = Energy efficient connected Watts from table located in Reference Tables Section.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[5] The value for Residential lighting is assumed to be 1.0.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[5] The value for Residential lighting is assumed to be 1.0.

Load Shapes

For prescriptive interior lighting C&I use # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and where C&I cooling savings are characterized, use #15 (Commercial A/C) cooling energy savings.

For prescriptive exterior lighting C&I applications; #13 (Commercial Outdoor Lighting)

For Residential or in-unit multifamily applications; #1 (Residential Indoor Lighting).

For Residential Exterior applications; #2 (Residential Outdoor Lighting).

For C&I Smartlight; #101 (Commercial EP Lighting with Cooling Bonus)[15]

1a Residential Indoor Lighting
2a Residential Outdoor Lighting
12d Commercial Indoor Lighting - Blended
13a Commercial Outdoor Lighting
15c Commercial A/C
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9%	35.0%	13.0%	15.1%	29.8%	8.2%
2	Residential Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	34.6%	1.8%
12	Commercial Indoor Lighting - Blended	Active	48.8%	19.5%	22.2%	9.5%	46.9%	67.9%
13	Commercial Outdoor Lighting	Active	20.5%	50.6%	6.1%	22.8%	70.2%	3.7%
15	Commercial A/C	Active	18.0%	10.0%	46.0%	26.0%	0.0%	34.2%
101	Commercial EP Lighting with cooling bonus	Active	47.7%	19.2%	23.0%	10.1%	33.8%	68.1%

Net Savings Factors

Measures

LBLT8LED	LED Linear Replacement Lamp (TLED)
LBLHDLED	LED HID Lamp Replacement-Type B/C (direct-wired)
LBLPBLED	LED Pin-based Replacement Lamp for CFLs (using existing ballast)

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6013UPST [is base track]	Upstream - Commercial
6032EPEP [is base track]	Efficient Products - Residential
6032UPST [6032EPEP]	Upstream - Residential
6013EPEP [6032EPEP]	Efficient Products - Commercial

Lifetimes

Measure lifetime is the rated lifetime (50,000 hours as required by DLC) divided by annual operating hours. Measure lifetime is capped at 15 years.

LED Category	Customer Type	Measure Lifetime
LED Linear Replacement	Commercial	14.1
	Residential	15
LED HID Replacement Lamps	Commercial	13.8
	Residential	15
Pin Base Lamps	Commercial	15
	Residential	15

Measure Cost

Refer to "Wattage Assumptions, Deemed Savings, and Measure Costs" tables in the Reference Tables section for measure costs.

O&M Cost Adjustments

Refer to the "O&M Assumptions" tables in the Reference Tables section for O&M cost adjustments.

Reference Tables

See EVT_LED Other Lamp_Analysis_ 2021.xlsx for analysis and references. Efficient wattage based on average of lamps on DLC QPL accessed 11/2020 (see 'DLC_112020_Other Lamps.xls').

Deemed Savings and Measure Costs

LED Linear Replacement Lamps (TLED) Wattage Assumptions, Deemed Savings, and Measure Costs

EE Measure Description	WattsEE	Baseline Description	$Watts_{Base}$	Market	ΔkW	ΔkWh	ΔMMBtu	EE Cost	Baseline Cost	Incremental Cost	Measure Code	Item Code
LED Linear Replacement Lamp (TLED)	15.7	Weighted mix	29.5	C&I Rx	0.01374	Dept on Hours		$18.71	$6.62	$12.09	LBLT8LED	BES-LEDLIN-A
				C&I EP and Smartlight	0.01374	45.9	0.029					BES-UPLEDLIN-A
				Res EP and Smartlight	0.01314	13.0	0.000					RES-UPLEDLIN-A

LED HID Replacement Lamps Wattage Assumptions, Deemed Savings, and Measure Costs

EE Measure Description	WattsEE	Baseline Description	$Watts_{Base}$	Market	ΔkW	ΔkWh	ΔMMBtu	EE Cost	Baseline Cost	Incremental Cost	Measure Code	Item Code
LED HID Replacement Lamps Type B/C, <= 5,000 lumens	33.3	100W Metal Halide	113.6	C&I Rx	0.07484	Dept on Hours		$73.63	$20.00	$54.00	LBLHDLED	BES-MOG-A
				C&I Smartlight	0.07484	254.3	0.161					BES-UPMOG-A
				Res Smartlight	0.07786	159.2	0.000					RES-UPMOG-A
LED HID Replacement Lamps Type B/C, 5,001-10,000 lumens	62.5	175W Pulse Start Metal Halide	198.9	C&I Rx	0.12715	Dept on Hours		$93.45	$25.00	$68.00		BES-MOG-B
				C&I Smartlight	0.12715	432.0	0.273					BES-UPMOG-B
				Res Smartlight	0.13229	270.4	0.000					RES-UPMOG-B
LED HID Replacement Lamps Type B/C, >10,000 lumens	119.3	Weighted Mix	322.0	C&I Rx	0.18896	Dept on Hours		$172.39	$124.73	$48.00		BES-MOG-E
				C&I Smartlight	0.18896	642.0	0.406					BES-UPMOG-E
				Res Smartlight	0.19660	401.8	0.000					RES-UPMOG-E

LED Pin-Base CFL Replacement Lamps Wattage Assumptions, Deemed Savings, and Measure Costs

EE Measure Description	WattsEE	Baseline Description	$Watts_{Base}$	Market	ΔkW	ΔkWh	ΔMMBtu	EE Cost	Baseline Cost	Incremental Cost	Measure Code	Item Code
LED Pin-Base CFL Replacement Lamp	9.8	Weighted Mix	20.0	C&I Rx	0.00953	Dept on Hours		$19.69	$5.93	$13.76	LBLPBLED	BES-PIN-D
				C&I Smartlight	0.00953	27.8	0.018					BES-UPPIN-D
				Res Smartlight	0.00992	9.8	0.000					RES-UPPIN-D

O&M Adjustments

LED Linear Replacement Lamps (TLED) O&M Assumptions

EE Measure Description	LED Lamp Life (hrs)	LED Lamp Replacement Cost	Baseline Lamp Life (hrs)	Baseline Lamp Replacement Cost Combined
LED Linear Replacement Lamp (TLED)	50,000	$18.71	23,445	$6.62

LED HID Replacement Lamps O&M Assumptions

EE Measure Description	LED Lamp Life (hrs)	LED Lamp Replacement Cost	Baseline Lamp Life (hrs)	Baseline Lamp Replacement Cost Combined	Baseline Ballast Life (hrs)	Baseline Ballast Replacement Cost Combined
LED Mogul Base HID Replacement Lamps Type B/C, <= 5,000 lumens	50,000	$75.00	15,000	$58.00	40,000	$102.50
LED Mogul Base HID Replacement Lamps Type B/C, 5,001-10,000 lumens	50,000	$108.78	15,000	$63.00	40,000	$112.50
LED Mogul Base HID Replacement Lamps Type B/C, >10,000 lumens	50,000	$172.39	15,000	$69.11	40,000	$124.73

LED Pin-Base CFL Replacement Lamps O&M Assumptions

EE Measure Description	LED Lamp Life (hrs)	LED Lamp Replacement Cost	Baseline Lamp Life (hrs)	Baseline Lamp Replacement Cost Combined
LED Pin-Base CFL Replacement Lamp	50,000	$19.69	10,000	$5.93

Footnotes

[1] 3-year ISR for commercial LED linear lamps from DNV GL, "Impact Evaluation of PY2015 Massachusetts Commercial and Industrial Upstream Lighting Initiative," November 22, 2017, page 32, Table 4-2.

[2] The ISR calculation for residential lamps follows the lifetime ISR approach from NREL, "Chapter 6: Residential Lighting Protocol," Oct 2017 from the Uniform Methods Protocol. The UMP protocol recommends truncating the ISR at the measure's EISA sunset date (date the program plans to end the measure based on the EISA backstop). EVT accounts for the shifting baseline through a mid-life adjustment and caps installations at 10 years for all lamp categories. The installation trajectory is from NMR Group, "RLPNC Study 17-9 2017-18 Residential Lighting Market Assessment Study," March 28, 2018, page 37. NMR observed that 32% of bulbs are installed in year 2 and 18% in year 3. NMR's recommend lifetime ISR methodology assumes that 32% of bulbs are installed in year 1 and 18 percent of bulbs still in storage are installed in each subsequent year. The calculation also assumes a 1st Year ISR of 88% (average of 1st year ISR of 90% from NMR Group, Inc., "Efficiency Maine Retail Lighting Program Overall Evaluation Report FINAL," 4/16/2015, page 14, Table 2-1, 95% from NMR Group, Inc., "Connecticut LED Lighting Study Report (R154) FINAL," 1/28/2016, page V, Table 1, and 80% from NMR Group, "RLPNC Study 17-9 2017-18 Residential Lighting Market Assessment Study," March 28, 2018, page 35, Table 10) and a discount rate of 3.00% based on the Vermont societal cost test. See file EVT_SMARTLIGHT_Dec 2018 v4.xlsx for calculaton details.

[3] Commercial LED HID Replacement Lamps and Pin Base Lamps ISR is the 3-year ISR for LED lamps from DNV GL, "Massachusetts Commercial and Industrial Upstream Lighting Program: "In Storage" Lamps Follow-Up Study," March 27, 2015, page 5

[4] Leakage Rate to account for LED Linear Replacement Lamps sold to customers outside of the program area via the EP program. LED HID Replacement Lamps and Pin Base Lamps are part of the Smartlight Program and end user information is collected at point of sale. The leakage rate of 1.5% was agreed to by EVT and DPS during October 2017 TAG. This value is an estimate based on leakage rates used by other programs, geographic factors, and a consideration of similar lighting programs in surrounding service territories.

[5] The default waste heat factors for demand and energy for commercial indoor fixtures are from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[6] Operating hours for Commercial LED Linear Replacements are based on Efficiency Vermont data for prescriptive applications from 2015 through May 2017.

[7] Operating hours for Residential LED Linear Replacement Lamps, LED Troffers, and Pin Base Lamps are based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[8] Operating hours for LED HID Replacement Lamps are based on Efficiency Vermont data for prescriptive applications from 2015 through October 2018.

[9] Operating hours for Residential LED HID Replacement Lamps based on household exterior average 5.6 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[10] Operating hours for Commercial Pin Base Lamps based on review of Efficiency Vermont custom QA projects.

[11] Average AFUE of the HVAC heating equipment is based on the weighted average of existing commercial heating systems, as sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[12] The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[13] From "Calculating lighting and HVAC Interactions", Table 1, ASHRAE Journal November 1993. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[14] 2017 ASHRAE Handbook Fundamentals (p. 16.3): "Conventional all-air air-handling systems for commercial and institutional buildings often have approximately 10 to 40% outside air." For more information, please see the spreadsheet, “EVT Lighting WHF Research_Prescriptive_2020.xlsx”.

[15] Based on Commercial “Small” Lighting coincidence factors from KEMA; “C&I Lighting Load Shape Project Final Report,” July 19, 2011, prepared for the Regional Evaluation, Measurement and Verification Form, submitted to NEEP. The winter coincidence factor has been adjusted to remove the cooling bonus from winter peak demand.

LED ENERGY STAR Screw Based Lamps

Measure Number: CR-LTG-LEDSB b
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Lighting

Update Summary

The following revisions have been made to the measure:

- Since EISA backstop not enacted, language updated.
- Baseline watts now based on weighted mix (therefore NTG =1) , and midlife adjustment based upon replacement lamp forecast.
- Smartlight and EP are combined (now applying approved leakage rate to both programs)
- Costs updated and O&M impacts calculated based on weighted baseline mix.
- 3 year assumptions calculated

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- KEMA Inc., "Impact Evaluation of the Massachusetts Upstream Lighting Program FINAL REPORT", February 2014.
- NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014.
- NMR_R154 - CT LED Lighting Study_Final Report_1
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- CEE_Residential Lighting Initiative_Oct 2017
- EVT Lighting WHF Research Prescriptive_2020
- 2019_ssl-energy-savings-forecast
- National Grid Smart Lighting System Report
- 2021-2023__EVT Lamp Analysis

Description

An ENERGY STAR Integrated Screw Based SSL (LED) Lamp (specification effective October 2017) is installed in place of a baseline incandescent or halogen lamp. This measure is broken down in to Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Candelabra Bulbs) and Directional (PAR Lamps, Reflectors, MR16). Further, each bulb type is broken down into Consortium for Energy Efficiency (CEE) lighting specification tiers 1 and 2[1]. For programs that track ENERGY STAR-qualified distributed bulbs but lack sufficient data to identify bulbs as either CEE Tier 1 or 2, an ENERGY STAR 2.1 'Blended' tier is provided. The blended tier is an average of the CEE tiers, weighted by EVT sales data. Note that CEE Tier 1 meets the minimum ENERGY STAR 2.1 requirements and Tier 2 exceeds this specification.

Assumptions are provided for the following markets: Efficient Products Retail, Efficient Products Free, Low Income, SMARTLIGHT, Residential Direct Install, and Home Energy Visit ENERGY STAR LED Bulb Dropship.

Market	Description
Efficient Products Retail (Residential and Commercial)	This is for retail sales for Residential or Commercial customers.
Efficient Products Free	An LED lamp is received free of charge at an Efficiency Vermont event or as part of a targeted campaign and is installed in a Residential fixture.
Low Income	Inclusive of the traditional Foodbanks, but also can include other organizations that provide "free" bulbs and provide documentation stating that clientele are in an applicable income bracket.
SMARTLIGHT (Residential and Commercial)	In reference to PIP #67a: Upstream Distributor Incentive Model, Efficiency Vermont offers "upstream" incentives to Vermont electrical distributors for certain eligible LED lamps.
Residential Direct Install	LED lamp is physically installed by an efficiency program representative through a direct install program
LED Dropship	An EVT consultant visits a residential home, identifies high use sockets with inefficient (incandescent or halogen) bulbs, and places an order with a local distributor for replacement efficient LEDs. A distributor ships products to customer, free of charge. Instructions for which bulbs are to be installed and where are included in the package.

Program Type

Calculation: Time of Sale (Market Opportunity)

Program Delivery / Implementation Type: Midstream, Direct Install, Free

Baseline Efficiencies

Federal legislation stemming from the Energy Independence and Security Act of 2007 began the phasing out of omnidirectional incandescent bulbs. From 2012, 100W incandescents could no longer be manufactured, followed by restrictions on 75W in 2013 and 60W/40W in 2014.

Additionally, an EISA backstop provision was included that would require replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. However, in December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that this more stringent standard was not economically justified.

The natural growth of LED market share however, has and will continue to grow over the lifetime of the LED measures installed. Therefore a forecast of the baseline growth of LED has been developed, based upon historical growth rates provided via CREED LightTracker data for no-program states, and review of projections provided by the Department of Energy.

This baseline forecast is used to estimate a weighted average baseline wattage for the next three years, and also used to estimate how replacement lamps would change over the lifetime of the LED. A single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings.

Note that by using the estimated weighted average baseline, the NTG for this measure should be 1.0.

High Efficiency

The high efficiency wattage is assumed to be a CEE Tier 1 or Tier 2 qualified lamp. ENERGY STAR 'Blended' values should be used if the CEE Tier is unknown. See "2021-2023 EVT Lamp Analysis.xls" for details.

Algorithms

Electric Demand Savings

ΔkW	$= (\Delta kWh \times WHF_d / WHF_e) / HOURS$

Symbol Table

Electric Energy Savings

ΔkWh	$= (((((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times HOURS) + (Connected \times Watts_{EE} / StudyLEDW \times ConnectedkWhSavings)) \times WHF_e \times (1-LR)$

Symbol Table

Heating Penalty

$\Delta MMBTU_{WH}$	$= (\Delta kWh / WHF_e) \times 0.003412 \times (1 - OA) \times AR \times HF \times DFH / \eta Heat$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure.
ΔkWh	=	Gross customer annual kWh savings for the measure.
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
ηHeat	=	Average heating system efficiency = 86.8%[13]
0.003412	=	Conversion from kWh to MMBTU
AR	=	Aspect ratio factor; the typical square footage of commercial buildings within 15 feet of exterior wall. The default value is 60%[14]
Connected	=	1 if Connected Lamp, 0 if not
ConnectedkWhSavings	=	kWh Savings from connected capabilities = 5.1[4]
DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting.[15] Assumed to be 0.0 for residential lighting.
HOURS	=	Average hours of use per year.

Market	Annual Hours
Commercial	3,979[5]
Residential Direct Install Exterior	2,044[6]
Residential Interior	986[7]

ISR	=	In service rate or the percentage of units rebated that actually get used. Dependent on **Market:**

Market	ISR
Residential Direct Install	97%[8]
Efficient Products Retail, SMARTLIGHT (Residential), Low Income, and LED Dropship	97%[9]
Efficient Products Retail and SMARTLIGHT (Commercial)	84.6%[10]
Efficient Products Free	70%[11]

LR	=	Leakage Rate to account for bulbs sold to customers outside of the program area = 0.015[12] for Efficient Product Retail and SMARTLIGHT = 0 for Efficient Products Free, Low Income, Residential Direct Install, and LED Dropship
OA	=	Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[16]
StudyLEDW	=	LED Wattage from Connected Study. Used to adjust study findings relative to LED wattage of measure. = 11.5 W
$Watts_{BASE}$	=	Baseline connected kW. See assumptions in table below.
$Watts_{EE}$	=	Energy efficient connected kW. See assumptions in table below.
WHF_d	=	Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[3] The value for residential lighting is assumed to be 1.0.
WHF_e	=	Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[3] The value for residential lighting is assumed to be 1.0.

Values used in algorithm and results:[2]

Program Type	Lamp Type	ENERGY STAR 2.1 / CEE Tier	LED	Baseline Watts			2021				2022				2023				Item Code
			(Watts)	2021	2022	2023	ΔkW	ΔkWh	Year of Adj	Adj	ΔkW	ΔkWh	Year of Adj	Adj	ΔkW	ΔkWh	Year of Adj	Adj	
Efficient Products Retail and SMARTLIGHT (Residential)	Omnidirectional Connected	Blended	10	26.6	25.3	23.9	0.02040	20.1			0.01908	18.8			0.01776	17.5			EPROMNICB SLROMNICB
		CEE Tier 1	9.4	25	23.7	22.4	0.01908	18.8	2024	0.54	0.01786	17.6	2025	0.54	0.01664	16.4	2026	0.55	EPROMNIC1 SLROMNIC1
		CEE Tier 2	12.9	34.9	33.2	31.3	0.02679	26.4			0.02506	24.7			0.02324	22.9			EPROMNIC2 SLROMNIC2
	Decorative Connected	Blended	4.7	19.7	18	16.9	0.01644	16.2			0.01481	14.6			0.01380	13.6			EPRDECOCB SLRDECOCB
		CEE Tier 1	5	19.6	18	16.9	0.01624	16	2024	0.7	0.01461	14.4	2025	0.77	0.01360	13.4	2026	0.83	EPRDECOC1 SLRDECOC1
		CEE Tier 2	4.3	19.8	18.1	16.9	0.01664	16.4			0.01502	14.8			0.01400	13.8			EPRDECOC2 SLRDECOC2
	Directional Connected	Blended	9.7	17.9	17.4	16.9	0.01218	12			0.01167	11.5			0.01116	11			EPRDIRECB SLRDIRECB
		CEE Tier 1	9.5	17.5	17	16.5	0.01187	11.7	2024	0.73	0.01136	11.2	2025	0.74	0.01086	10.7	2026	0.74	EPRDIREC1 SLRDIREC1
		CEE Tier 2	10.9	20.4	19.8	19.2	0.01390	13.7			0.01329	13.1			0.01279	12.6			EPRDIREC2 SLRDIREC2
Efficient Products Retail and SMARTLIGHT (Commercial)	Omnidirectional Connected	Blended	10	26.6	25.3	23.9	0.01553	61.8			0.01438	57.2			0.01314	52.3			EPCOMNICB SLCOMNICB
		CEE Tier 1	9.4	25	23.7	22.4	0.01455	57.9	2024	0.54	0.01347	53.6	2025	0.54	0.01231	49	2026	0.55	EPCOMNIC1 SLCOMNIC1
		CEE Tier 2	12.9	34.9	33.2	31.3	0.02046	81.4			0.01892	75.3			0.01732	68.9			EPCOMNIC2 SLCOMNIC2
	Decorative Connected	Blended	4.7	19.7	18	16.9	0.01352	53.8			0.01209	48.1			0.01111	44.2			EPCDECOCB SLCDECOCB
		CEE Tier 1	5	19.6	18	16.9	0.01319	52.5	2024	0.7	0.01181	47	2025	0.77	0.01088	43.3	2026	0.83	EPCDECOC1 SLCDECOC1
		CEE Tier 2	4.3	19.8	18.1	16.9	0.01385	55.1			0.01236	49.2			0.01138	45.3			EPCDECOC2 SLCDECOC2
	Directional	Blended	9.7	17.9	17.4	16.9	0.00822	32.7			0.00777	30.9			0.00731	29.1			EPCDIRECB SLCDIRECB
		CEE	9.5	17.5	17	16.5	0.00799	31.8	2024	0.73	0.00756	30.1	2025	0.74	0.00711	28.3	2026	0.74	EPCDIREC1

	Connected	Tier 1	9.5	17.5	17	16.5	0.00799	31.8	2024	0.73	0.00756	30.1	2025	0.74	0.00711	28.3	2026	0.74	SLCDIREC1
		CEE Tier 2	10.9	20.4	19.8	19.2	0.00945	37.6			0.00895	35.6			0.00842	33.5			EPCDIREC2 SLCDIREC2
Efficient Products Free	Omnidirectional	Blended	10	26.6	25.3	23.9	0.01168	11.5	2024	0.42	0.01073	10.6	2025	0.4	0.00974	9.6	2026	0.39	FREEOMNIB
		CEE Tier 1	9.4	25	23.7	22.4	0.01094	10.8			0.01005	9.9			0.00912	9			FREEOMNI1
		CEE Tier 2	12.9	34.9	33.2	31.3	0.01540	15.2			0.01415	13.9			0.01285	12.7			FREEOMNI2
	Decorative	Blended	4.7	19.7	18	16.9	0.01053	10.4	2024	0.66	0.00937	9.2	2025	0.74	0.00859	8.5	2026	0.8	FREEDECOB
		CEE Tier 1	5	19.6	18	16.9	0.01024	10.1			0.00912	9			0.00835	8.2			FREEDECO1
		CEE Tier 2	4.3	19.8	18.1	16.9	0.01083	10.7			0.00964	9.5			0.00883	8.7			FREEDECO2
	Directional	Blended	9.7	17.9	17.4	16.9	0.00578	5.7	2024	0.59	0.00541	5.3	2025	0.59	0.00504	5	2026	0.59	FREEDIREB
		CEE Tier 1	9.5	17.5	17	16.5	0.00561	5.5			0.00526	5.2			0.00490	4.8			FREEDIRE1
		CEE Tier 2	10.9	20.4	19.8	19.2	0.00667	6.6			0.00625	6.2			0.00582	5.7			FREEDIRE2
	Omnidirectional Connected	Blended	10	26.6	25.3	23.9	0.01613	15.9	2024	0.54	0.01522	15	2025	0.54	0.01421	14	2026	0.55	FREEOMNICB
		CEE Tier 1	9.4	25	23.7	22.4	0.01512	14.9			0.01431	14.1			0.01329	13.1			FREEOMNIC1
		CEE Tier 2	12.9	34.9	33.2	31.3	0.02121	20.9			0.01999	19.7			0.01867	18.4			FREEOMNIC2
	Decorative Connected	Blended	4.7	19.7	18	16.9	0.01258	12.4	2024	0.7	0.01147	11.3	2025	0.77	0.01065	10.5	2026	0.83	FREEDECOCB
		CEE Tier 1	5	19.6	18	16.9	0.01248	12.3			0.01136	11.2			0.01055	10.4			FREEDECOC1
		CEE Tier 2	4.3	19.8	18.1	16.9	0.01279	12.6			0.01157	11.4			0.01076	10.6			FREEDECOC2
	Directional Connected	Blended	9.7	17.9	17.4	16.9	0.01015	10	2024	0.73	0.00974	9.6	2025	0.74	0.00944	9.3	2026	0.74	FREEDIRECB
		CEE Tier 1	9.5	17.5	17	16.5	0.00984	9.7			0.00954	9.4			0.00913	9			FREEDIREC1
		CEE Tier 2	10.9	20.4	19.8	19.2	0.01157	11.4			0.01116	11			0.01076	10.6			FREEDIREC2
Non Low Income Dropship	Omnidirectional	Blended	10	26.6	25.3	23.9	0.01594	15.7	2024	0.42	0.01465	14.4	2025	0.4	0.01330	13.1	2026	0.39	DSNOMNIB
		CEE Tier 1	9.4	25	23.7	22.4	0.01493	14.7			0.01372	13.5			0.01245	12.3			DSNOMNI1
		CEE Tier 2	12.9	34.9	33.2	31.3	0.02102	20.7			0.01931	19			0.01754	17.3			DSNOMNI2
	Decorative	Blended	4.7	19.7	18	16.9	0.01437	14.2	2024	0.66	0.01279	12.6	2025	0.74	0.01172	11.6	2026	0.8	DSNDECOB
		CEE Tier 1	5	19.6	18	16.9	0.01397	13.8			0.01244	12.3			0.01140	11.2			DSNDECO1
		CEE Tier 2	4.3	19.8	18.1	16.9	0.01478	14.6			0.01316	13			0.01206	11.9			DSNDECO2
	Directional	Blended	9.7	17.9	17.4	16.9	0.00789	7.8	2024	0.59	0.00739	7.3	2025	0.59	0.00688	6.8	2026	0.59	DSNDIREB
		CEE Tier 1	9.5	17.5	17	16.5	0.00766	7.5			0.00718	7.1			0.00669	6.6			DSNDIRE1
		CEE Tier 2	10.9	20.4	19.8	19.2	0.00910	9			0.00853	8.4			0.00795	7.8			DSNDIRE2
Low Income Retail and Dropship	Omnidirectional	Blended	10	31.3	29.9	28.2	0.02071	20.4	2024	0.42	0.01930	19	2025	0.41	0.01774	17.5	2026	0.41	LIFOMNIB
		CEE Tier 1	9.4	29.3	28	26.5	0.01936	19.1			0.01806	17.8			0.01660	16.4			LIFOMNI1
		CEE Tier 2	12.9	41.1	39.2	37.1	0.02734	26.9			0.02546	25.1			0.02341	23.1			LIFOMNI2
	Decorative	Blended	4.7	30.4	24	20.9	0.02496	24.6	2024	0.66	0.01874	18.5	2025	0.74	0.01580	15.6	2026	0.8	LIFDECOB
		CEE Tier 1	5	30	23.8	20.8	0.02427	23.9			0.01822	18			0.01536	15.1			LIFDECO1
		CEE Tier 2	4.3	30.8	24.2	21.1	0.02569	25.3			0.01929	19			0.01626	16			LIFDECO2
	Directional	Blended	9.7	24.8	19.4	18.3	0.01469	14.5	2024	0.59	0.00947	9.3	2025	0.59	0.00832	8.2	2026	0.59	LIFDIREB
		CEE Tier 1	9.5	24.2	18.9	17.8	0.01427	14.1			0.00920	9.1			0.00808	8			LIFDIRE1
		CEE Tier 2	10.9	28.4	22.1	20.8	0.01697	16.7			0.01094	10.8			0.00961	9.5			LIFDIRE2
	Omnidirectional Connected	Blended	10	31.3	29.9	28.2	0.02516	24.8	2024	0.54	0.02374	23.4	2025	0.54	0.02222	21.9	2026	0.55	LIFOMNICB
		CEE Tier 1	9.4	29.3	28	26.5	0.02354	23.2			0.02222	21.9			0.02080	20.5			LIFOMNIC1
		CEE Tier 2	12.9	41.1	39.2	37.1	0.03318	32.7			0.03125	30.8			0.02922	28.8			LIFOMNIC2
	Decorative Connected	Blended	4.7	30.4	24	20.9	0.02709	26.7	2024	0.7	0.02080	20.5	2025	0.77	0.01786	17.6	2026	0.83	LIFDECOCB
		CEE Tier 1	5	30	23.8	20.8	0.02648	26.1			0.02050	20.2			0.01766	17.4			LIFDECOC1
		CEE Tier 2	4.3	30.8	24.2	21.1	0.02760	27.2			0.02121	20.9			0.01816	17.9			LIFDECOC2
	Directional Connected	Blended	9.7	24.8	19.4	18.3	0.01908	18.8	2024	0.73	0.01380	13.6	2025	0.74	0.01268	12.5	2026	0.74	LIFDIRECB
		CEE Tier 1	9.5	24.2	18.9	17.8	0.01857	18.3			0.01350	13.3			0.01238	12.2			LIFDIREC1
		CEE Tier 2	10.9	28.4	22.1	20.8	0.02182	21.5			0.01583	15.6			0.01451	14.3			LIFDIREC2
Low Income* and Residential Direct Install Interior	Omnidirectional	Blended	10	52.4	52.2	52	0.04113	40.5	2024	0.42	0.04095	40.4	2025	0.4	0.04075	40.2	2026	0.39	DIIOMNI1
		CEE Tier 1	9.4				0.04170	41.1			0.04152	40.9			0.04132	40.7			DIIOMNI2
		CEE Tier 2	12.9				0.03823	37.7			0.03805	37.5			0.03785	37.3			DIIOMNI3
	Decorative	Blended	4.7	40.2	40.2	40.1	0.03446	34	2024	0.66	0.03443	33.9	2025	0.74	0.03439	33.9	2026	0.8	DIIDECO1
		CEE Tier 1	5				0.03413	33.6			0.03410	33.6			0.03406	33.6			DIIDECO2
		CEE Tier 2	4.3				0.03481	34.3			0.03478	34.3			0.03474	34.2			DIIDECO3
	Directional	Blended	9.7	35.4	35.4	35.4	0.02497	24.6	2024	0.59	0.02497	24.6	2025	0.59	0.02497	24.6	2026	0.59	DIIDIRE1
		CEE Tier 1	9.5				0.02519	24.8			0.02518	24.8			0.02518	24.8			DIIDIRE2
		CEE Tier 2	10.9				0.02383	23.5			0.02383	23.5			0.02382	23.5			DIIDIRE3
	Omnidirectional Connected	Blended	10	52.4	52.2	52	0.04556	44.9	2024	0.54	0.04546	44.8	2025	0.54	0.04526	44.6	2026	0.55	DIIOMNIC1
		CEE Tier 1	9.4				0.04587	45.2			0.04576	45.1			0.04556	44.9			DIIOMNIC2
		CEE Tier 2	12.9				0.04404	43.4			0.04384	43.2			0.04363	43			DIIOMNIC3
	Decorative Connected	Blended	4.7	40.2	40.2	40.1	0.03653	36	2024	0.7	0.03653	36	2025	0.77	0.03653	36	2026	0.83	DIIDECOC1
		CEE Tier 1	5				0.03633	35.8			0.03633	35.8			0.03633	35.8			DIIDECOC2
		CEE Tier 2	4.3				0.03673	36.2			0.03673	36.2			0.03663	36.1			DIIDECOC3
	Directional Connected	Blended	9.7	35.4	35.4	35.4	0.02933	28.9	2024	0.73	0.02933	28.9	2025	0.74	0.02933	28.9	2026	0.74	DIIDIREC1
		CEE Tier 1	9.5				0.02943	29			0.02943	29			0.02943	29			DIIDIREC2
		CEE Tier 2	10.9				0.02872	28.3			0.02872	28.3			0.02872	28.3			DIIDIREC3
Low Income* and Residential	Omnidirectional	Blended	10	52.4	52.2	52	0.04113	84.1	2024	0.42	0.04095	83.7	2025	0.41	0.04075	83.3	2026	0.41	DIXOMNI1
		CEE Tier 1	9.4				0.04170	85.2			0.04152	84.9			0.04132	84.5			DIXOMNI2
		CEE Tier 2	12.9				0.03823	78.1			0.03805	77.8			0.03785	77.4			DIXOMNI3
	Decorative	Blended	4.7	40.2	40.2	40.1	0.03446	70.4	2024	0.66	0.03443	70.4	2025	0.74	0.03439	70.3	2026	0.8	DIXDECO1
		CEE Tier 1	5				0.03413	69.8			0.03410	69.7			0.03406	69.6			DIXDECO2
		CEE Tier 2	4.3				0.03481	71.1			0.03478	71.1			0.03474	71			DIXDECO3
	Directional	Blended	9.7	35.4	35.4	35.4	0.02497	51	2024	0.59	0.02497	51	2025	0.59	0.02497	51	2026	0.59	DIXDIRE1
		CEE Tier 1	9.5				0.02519	51.5			0.02518	51.5			0.02518	51.5			DIXDIRE2
		CEE Tier 2	10.9				0.02383	48.7			0.02383	48.7			0.02382	48.7			DIXDIRE3

Residential Direct Install Exterior	Omnidirectional Connected	Blended	10	52.4	52.2	52	0.04330	88.5	2024	0.54	0.04310	88.1	2025	0.54	0.04291	87.7	2026	0.55	DIXOMNIC1
		CEE Tier 1	9.4				0.04374	89.4			0.04354	89			0.04335	88.6			DIXOMNIC2
		CEE Tier 2	12.9				0.04105	83.9			0.04085	83.5			0.04066	83.1			DIXOMNIC3
	Decorative Connected	Blended	4.7	40.2	40.2	40.1	0.03547	72.5	2024	0.7	0.03542	72.4	2025	0.77	0.03542	72.4	2026	0.83	DIXDECOC1
		CEE Tier 1	5				0.03523	72			0.03518	71.9			0.03513	71.8			DIXDECOC2
		CEE Tier 2	4.3				0.03576	73.1			0.03571	73			0.03567	72.9			DIXDECOC3
	Directional Connected	Blended	9.7	35.4	35.4	35.4	0.02705	55.3	2024	0.73	0.02705	55.3	2025	0.74	0.02705	55.3	2026	0.74	DIXDIREC1
		CEE Tier 1	9.5				0.02725	55.7			0.02725	55.7			0.02725	55.7			DIXDIREC2
		CEE Tier 2	10.9				0.02617	53.5			0.02617	53.5			0.02617	53.5			DIXDIREC3

*Low Income Itemcodes delineated by prefix LI.

Using default values, the MMBtu penalties for each commercial bulb type are provided below. Penalty values are not provided for residential markets because Efficiency Vermont does not calculate interactive effects for residential lighting.Oil heating is assumed typical for commercial buildings.

Program Type	Lamp Type	ENERGY STAR 2.1 / CEE Tier	ΔMMBtu
Efficient Products Retail and SMARTLIGHT (Commercial)	Omnidirectional Connected	Blended	0.039
		CEE Tier 1	0.037
		CEE Tier 2	0.051
	Decorative Connected	Blended	0.034
		CEE Tier 1	0.033
		CEE Tier 2	0.035
	Directional Connected	Blended	0.021
		CEE Tier 1	0.02
		CEE Tier 2	0.024

Baseline Adjustment

The natural growth of LED market share, has and will continue to grow over the lifetime of the LED measures installed. Therefore a forecast of the baseline growth of LED lamps has been developed, based upon historical growth rates provided via CREED LightTracker data for no-program states, and review of projections provided by the Department of Energy.

This forecast is used to estimate how baseline replacement lamps would change over the lifetime of the LED fixture. A single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. The appropriate adjustments as a percentage of the base year savings for each fixture type are provided in the table above

Operating Hours

See Algorithm Section above.

Load Shapes

Residential: Loadshape #1: Residential Indoor Lighting

Commercial: Loadshape #101: Commercial EP Lighting with Cooling Bonus[17]

1a Residential Indoor Lighting
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9%	35.0%	13.0%	15.1%	29.8%	8.2%
101	Commercial EP Lighting with cooling bonus	Active	47.7%	19.2%	23.0%	10.1%	33.8%	68.1%

Net Savings Factors

Measures

LBLLEDSC	LED Screw Base Lamp

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES
6020CUST [is base track]	6020CUST
6032UPST [6032EPEP]	Upstream - Residential
6013EPEP [6032EPEP]	Efficient Products - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	LBLLEDSC	0.90	1.00
Efficient Products - Residential	6032EPEP	LBLLEDSC	0.94	1.25
LISF Retrofit	6034LISF	LBLLEDSC	1.00	1.00
Res Retrofit	6036RETR	LBLLEDSC	0.90	1.00
RNC VESH	6038VESH	LBLLEDSC	0.88	1.10
6017PRES	6017PRES	LBLLEDSC	1.00	1.00
6017CUST	6017CUST	LBLLEDSC	1.00	1.00
6020PRES	6020PRES	LBLLEDSC	0.90	1.00
6020CUST	6020CUST	LBLLEDSC	0.90	1.00
Efficient Products - Residential	6032EPEP	LBLLEDSC	0.95	1.05
Upstream - Commercial	6013UPST	LBLLEDSC	0.95	1.05
Upstream - Commercial	6013UPST	LBLLEDSC	0.90	1.00
Efficient Products - Residential	6032EPEP	LBLLEDSC	0.90	1.00
Efficient Products - Residential	6032EPEP	LBLLEDSC	0.85	1.00
Upstream - Commercial	6013UPST	LBLLEDSC	0.85	1.00
Efficient Products - Residential	6032EPEP	LBLLEDSC	0.80	1.00
Upstream - Commercial	6013UPST	LBLLEDSC	0.80	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Lifetime is a function of the average hours of use of the luminaire.

Lamp Type	ENERGY STAR 2.1 / CEE Tier	Rated Life (Hours)	Residential Interior (Years)	Residential Exterior (Years)	Commercial (Years)
	Blended	21,764	15.0	10.6	5.5

Omnidirectional	CEE Tier 1	20,696	15.0	10.1	5.2
	CEE Tier 2	25,073	15.0	12.3	6.3
Decorative	Blended	20,494	15.0	10.0	5.2
	CEE Tier 1	21,124	15.0	10.3	5.3
	CEE Tier 2	19,414	15.0	9.5	4.9
Directional	Blended	25,299	15.0	12.4	6.4
	CEE Tier 1	25,126	15.0	12.3	6.3
	CEE Tier 2	25,457	15.0	12.5	6.4

'Rated life' based on CEE Tier/ENERGY STAR 2.1 qualfying product average-rated-life weighted by EVT Efficient Products sales data.Note all lifetimes are capped at 15 years (although their rated life/hours may be higher).

Measure Cost

The incremental cost for this measure is dependent on the baseline mix and provided in the table below:[18]

Lamp Type	ENERGY STAR 2.1 / CEE Tier	Incremental Cost 2021	2022	2023
Omnidirectional	Blended	$1.55	$1.42	$1.30
	CEE Tier 1	$1.39	$1.28	$1.17
	CEE Tier 2	$1.70	$1.57	$1.43
Decorative	Blended	$1.36	$1.21	$1.11
	CEE Tier 1	$1.23	$1.09	$1.00
	CEE Tier 2	$1.50	$1.33	$1.22
Directional	Blended	$0.89	$0.83	$0.77
	CEE Tier 1	$0.80	$0.75	$0.70
	CEE Tier 2	$0.98	$0.91	$0.85
Omnidirectional Connected	Blended	$11.55	$11.42	$11.30
	CEE Tier 1	$10.39	$10.28	$10.17
	CEE Tier 2	$12.70	$12.57	$12.43
Decorative Connected	Blended	$11.36	$11.21	$11.11
	CEE Tier 1	$10.23	$10.09	$10.00
	CEE Tier 2	$12.50	$12.33	$12.22
Directional Connected	Blended	$20.89	$20.83	$20.77
	CEE Tier 1	$18.80	$18.75	$18.70
	CEE Tier 2	$22.98	$22.91	$22.85

For Direct Install the full LED lamp cost plus labor (assumed $2.67) is provided below:

Lamp Type	ENERGY STAR 2.1 / CEE Tier	Direct Install Cost
Omnidirectional	Blended	$7.67
	CEE Tier 1	$6.90
	CEE Tier 2	$8.44
Decorative	Blended	$7.67
	CEE Tier 1	$6.90
	CEE Tier 2	$8.44
Directional	Blended	$12.67
	CEE Tier 1	$11.40
	CEE Tier 2	$13.94
Omnidirectional Connected	Blended	$17.67
	CEE Tier 1	$15.90
	CEE Tier 2	$19.44
Decorative Connected	Blended	$17.67
	CEE Tier 1	$15.90
	CEE Tier 2	$19.44
Directional Connected	Blended	$32.67
	CEE Tier 1	$29.40
	CEE Tier 2	$35.94

O&M Cost Adjustments

To account for the shift in baseline due to replacement lamps, the levelized baseline replacement cost over the lifetime of the LED is calculated. The key assumptions used in this calculation are documented below.

	Omnidirectional	Decorative	Directional	Assumed Lifetime (hours)
LED	$5.00	$5.00	$10.00	
CFL	$2.50	$3.00	$4.50	10,000
Halogen	$1.25	$1.75	$3.50	1,000
Incandescent	$0.50	$1.75	$3.50	1,000

The calculation results in the following assumptions of equivalent annual baseline replacement cost:

Lamp Type	O&M RES 2021	O&M RES 2022	O&M RES 2023	O&M C&I 2021	O&M C&I 2022	O&M C&I 2023
Omnidirectional	$0.30	$0.28	$0.25	$0.57	$0.53	$0.48
Decorative	$0.56	$0.49	$0.45	$1.00	$0.89	$0.81
Directional	$0.35	$0.33	$0.31	$0.67	$0.63	$0.59
Omnidirectional Connected	$0.30	$0.28	$0.25	$0.57	$0.53	$0.48
Decorative Connected	$0.56	$0.49	$0.45	$1.00	$0.89	$0.81
Directional Connected	$0.35	$0.33	$0.31	$0.67	$0.63	$0.59

Fossil Fuel Description

See Heating Increased Usage above.

Water Descriptions

There are no water algorithms or default values for this measure.

Footnotes

[1] Consortium for Energy Efficiency, "Residential Lighting Initiative", October 2017.

[2] For details on calculations, see "2021-2023 EVT Lamp Analysis.xls".

[3] The default waste heat factors for demand and energy for commercial indoor fixtures are from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[4] Based on "Home Energy Management System/ Cmart Lighting Pilot for National Grid's Massachusetts and Rhode Island Residential Energy Efficiency Programs", Final Report, National Grid, March 2019

[5] Commercial hours of use from Impact Evaluation of the Massachusetts Upstream Lighting Program, FINAL REPORT. KEMA Inc., "Impact Evaluation of the Massachusetts Upstream Lighting Program FINAL REPORT", February 2014. Page 1-8, Section 1.2.3.3.

[6] Based on a household exterior average 5.6 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[7] Based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[8] ISR for Residential Direct Install based on Illinois Technical Reference Manual for Energy Efficiency, Version 6.0, which accounts for bulb failures during the first year.

[9] The ISR calculation for Efficient Products Retail, SMARTLIGHT (residential), Low Income, and LED Dropship follows the lifetime ISR approach from NREL, "Chapter 6: Residential Lighting Protocol," Oct 2017 from the Uniform Methods Protocol. The UMP protocol recommends truncating the ISR at the measure's EISA sunset date (date the program plans to end the measure based on the EISA backstop). EVT accounts for the shifting baseline through a mid-life adjustment and caps installations at 10 years for all lamp categories. The installation trajectory is from NMR Group, "RLPNC Study 17-9 2017-18 Residential Lighting Market Assessment Study," March 28, 2018, page 37. NMR observed that 32% of bulbs are installed in year 2 and 18% in year 3. NMR's recommend lifetime ISR methodology assumes that 32% of bulbs are installed in year 1 and 18 percent of bulbs still in storage are installed in each subsequent year. The calculation also assumes a 1st Year ISR of 88% (average of 1st year ISR of 90% from NMR Group, Inc., "Efficiency Maine Retail Lighting Program Overall Evaluation Report FINAL," 4/16/2015, page 14, Table 2-1, 95% from NMR Group, Inc., "Connecticut LED Lighting Study Report (R154) FINAL," 1/28/2016, page V, Table 1, and 80% from NMR Group, "RLPNC Study 17-9 2017-18 Residential Lighting Market Assessment Study," March 28, 2018, page 35, Table 10) and a discount rate of 3.00% based on the Vermont societal cost test. See file "2021-2023 EVT Lamp Analysis.xls" for calculaton details. For Low Income programs, since the Foodbank's member food shelves are set-up like traditional grocery outlets and clients are self-limiting based on need, and for LED Dropship, energy consultants verify outlets with inefficient bulbs on site and then ship appropriate LED bulbs with installation instructions, Efficiency Vermont will use the ISR from the EP Retail program.

[10] Commercial ISR is the 3-year ISR for LED lamps from DNV GL, "Massachusetts Commercial and Industrial Upstream Lighting Program: "In Storage" Lamps Follow-Up Study," March 27, 2015, page 5

[11] Source for EP Free ISR: The 1st year ISR value for both CFL and LED bulbs in efficiency kits is 59% in the Illinois Technical Reference Manual for Energy Efficiency, Version 6.0 ("Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B."). Efficiency Vermont assumes the ISR for free LED bulbs is higher than for free CFL bulbs.

[12] A leakage rate of 1.5% was agreed to by EVT and DPS during October 2017 TAG. This value is an estimate based on leakage rates used by other programs, geographic factors, and a consideration of similar lighting programs in surrounding service territories.

[13] Average AFUE of the HVAC heating equipment is based on the weighted average of existing commercial heating systems, as sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[14] The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[15] From "Calculating lighting and HVAC Interactions", Table 1, ASHRAE Journal November 1993. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[16] 2017 ASHRAE Handbook Fundamentals (p. 16.3): "Conventional all-air air-handling systems for commercial and institutional buildings often have approximately 10 to 40% outside air." For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive_2020.xlsx".

[17] Based on Commercial "Small" Lighting coincidence factors from KEMA; "C&I Lighting Load Shape Project Final Report," July 19, 2011, prepared for the Regional Evaluation, Measurement and Verification Form, submitted to NEEP. The winter coincidence factor has been adjusted to remove the cooling bonus from winter peak demand.

[18] Costs are based on 2019/2020 EVT sales data for LED bulbs. See reference file "2021-2023 EVT Lamp Analysis.xls" .

Interior Agriculture LED Grow Light

Measure Number: VII-C-17 a
Portfolio: EVT TRM Portfolio 2019-02
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Lighting

Update Summary

New Measure

Referenced Documents

- VT SF Existing Homes Onsite Report - DRAFT 122117
- Energy Trust of Oregon Res Grow Light Research_Evergreen Economics_May 2018
- EVT_LED Ag Grow Light_Analysis_Apr 2019

Description

This measure is for the installation of LED grow lights for residential agricultural purposes in interior spaces. The assumption is the installed LEDs will be used for horticulture applications.

LEDs are a growing option for cultivating plants, and represent a significant efficiency increase over traditional HID grow lights. Different from LEDs designed for visual applications and illuminating spaces for the human eye, grow lights efficacy are measured by their photosynthetic photon flux density (PPFD), instead of lumens. LEDs also offer interactive cooling savings due to the reduction in waste heat from an HID fixture, which typically require an additional cooling source to maintain design cultivation temperatures and plant health.

Baseline Efficiencies

The baseline is assumed to be a high pressure sodium (HPS) lamp, which is the established grow light for horticulture applications. The lowest bin of energy savings has a mix of linear fluorescent fixtures typically used for starters and seedlings.

Efficient Equipment

The efficient equipment is an equivalent LED grow light that is considered a suitable replacement based on industry research and manufacturer specifications.

Algorithms

Electric Demand Savings

ΔkW	$= ((Watts_{BASE} - Watts_{EE}) / 1000) \times WHF_d$

Symbol Table

Electric Energy Savings

ΔkWh	$= ((Watts_{BASE} - Watts_{EE}) / 1000) \times Hours \times WHF_e$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for this measure
ΔkWh	=	Gross customer annual kWh savings for this measure
Hours	=	Annual lighting hours of use per year. This number is dependent on the quantity of production cycles of the plant per year. = 1,377 hours per cycle[5]
$Watts_{BASE}$	=	Connected wattage of the baseline lighting fixture. Please refer to the equivalent baseline wattage in the reference tables section.
$Watts_{EE}$	=	Connected wattage of the energy efficient lighting fixture. Please refer to the installed efficient wattage in the reference tables section.
WHF_d	=	Waste heat factor for demand to account for cooling interactive savings from efficient lighting. The waste heat factor varies based on the size of the baseline and efficient light fixture and the amount of waste heat that needs to be displaced. Please refer to the demand waste heat factor in the reference tables section.
WHF_e	=	Waste heat factor for energy to account for cooling interactive savings from efficient lighting. The waste heat factor varies based on the size of the baseline and efficient light fixture and the amount of waste heat that needs to be displaced. Please refer to the energy waste heat factor in the reference tables section.

Deemed Algorithm Assumptions - Wattage

Measure	Bin Range	Baseline Description	Watts Base	Watts EE
Panel LED	LED < 131W	T8 and T5HO 4' 2-4L fixtures	132	69
LED 200W	LED ≥ 132W and < 221W	400W HPS	460	180
LED 300W	LED ≥ 222W and < 417W	600W HPS	665	318
LED 600W	LED ≥ 418W and < 840W	1000W HPS	1,085	588

Deemed Algorithm Assumptions - Waste Heat Factors[1]

Measure	With Cooling[2]		Without Cooling		Unknown[3]	
	WHFd	WHFe	WHFd	WHFe	WHFd	WHFe
Panel LED	1.16	1.16	1	1	1.04	1.04
LED 200W	1.36	1.36	1	1	1.08	1.08
LED 300W	1.41	1.41	1	1	1.09	1.09
LED 600W	1.46	1.46	1	1	1.11	1.11

Deemed Energy and Demand Savings

Measure	Cooling	1 Cycle Indoor		2 Cycle Indoor		3 Cycle Indoor		4 Cycle Indoor		Unknown[4]	
		ΔkW Savings	ΔkWh Savings	ΔkW Savings	ΔkWh Savings	ΔkW Savings	ΔkWh Savings	ΔkW Savings	ΔkWh Savings	ΔkW Savings	ΔkWh Savings
Panel LED	With Cooling	0.073	101	0.073	201	0.073	302	0.073	402	0.073	334
LED 200W		0.381	524	0.381	1048	0.381	1573	0.381	2097	0.381	1739
LED 300W		0.489	674	0.489	1347	0.489	2021	0.489	2694	0.489	2234
LED 600W		0.726	999	0.726	1998	0.726	2997	0.726	3996	0.726	3314
Panel LED	Without	0.063	87	0.063	173	0.063	260	0.063	347	0.063	288
LED 200W		0.280	386	0.280	771	0.280	1156	0.280	1542	0.280	1279

LED 300W	Cooling	0.347	478	0.347	955	0.347	1433	0.347	1911	0.347	1585
LED 600W		0.497	684	0.497	1368	0.497	2053	0.497	2737	0.497	2270
Panel LED	Unknown	0.066	90	0.066	180	0.066	271	0.066	361	0.066	299
LED 200W		0.302	416	0.302	833	0.302	1249	0.302	1665	0.302	1381
LED 300W		0.378	521	0.378	1041	0.378	1562	0.378	2083	0.378	1727
LED 600W		0.552	760	0.552	1519	0.552	2278	0.552	3038	0.552	2519

Load Shapes

128a Residential Indoor Ag. Grow Light (1 cycle)
129a Residential Indoor Ag. Grow Light (2-3 cycles)
130a Residential Indoor Ag. Grow Light (4+ cycles)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
128	Residential Indoor Ag. Grow Light (1 cycle)	Active	65.0%	25.8%	5.1%	4.1%	0.0%	0.0%
129	Residential Indoor Ag. Grow Light (2-3 cycles)	Active	61.8%	24.3%	8.3%	5.6%	77.9%	0.0%
130	Residential Indoor Ag. Grow Light (4+ cycles)	Active	44.0%	17.2%	26.1%	12.7%	77.9%	93.0%

Net Savings Factors

Measures

LFHAGROW	LED Ag Grow Light

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	LFHAGROW	1.00	1.00

Lifetimes

The analysis period is the same as the lifetime, 15 years.

Measure Cost

All measure costs are assumed to be incremental costs vs. the market opportunity baselines.

Incremental Costs

Measure	Incremental Cost
Panel LED	$27
LED 200W	$270
LED 300W	$425
LED 600W	$600

O&M Cost Adjustment

Measure	LED Lamp Life (hours)	LED Replacement Cost	Baseline Lamp Life (hours)	Baseline Lamp Replacement Cost	Baseline Ballast Life (hours)	Baseline Ballast Replacement Cost
Panel LED	50,000	$90	27,000	$29	55,000	$47
LED 200W	50,000	$496	24,000	$31	40,000	$205
LED 300W	50,000	$768	24,000	$47	40,000	$229
LED 600W	50,000	$1,388	24,000	$80	40,000	$255

Footnotes

[1] The energy and demand waste heat factors account for only the cooling interactive savings from the efficient lighting. Per the "Energy Trust of Oregon Residential Lighting Report", Evergreen Economics, May 2018; "Despite the fact that LEDs produce less excess heat than other types of lighting, there were no statistically significant differences in the frequency of supplemental heating equipment used by LED-using and non-LED using growers. As a result, opted to exclude waste heating interactive effects for supplemental heating equipment as they were employed in similar fashion between baseline and efficient scenarios.

[2] The cooling interactive effects were calculated assuming mechanical cooling is needed to displace the excess heat given off by the baseline fixtures. The mechanical cooling equipment is assumed to be a window air conditioner with a capacity of 8,160 Btu/h and an efficiency of 10.1 EER as sourced from the average of existing equipment from the "Vermont Single-Family Existing Homes Onsite Report", NMR, December 2017. The excess heat needed to be displaced from the baseline fixture is calculated assuming the lamp's efficacy in being able to convert input wattage to output light. It is assumed that high pressure sodium lamps convert 30% of the input wattage into light; 70% for fluorescent lamps; and 85% for LEDs.

Opted to base the cooling interactive effects on a window air conditioner as it's the typical portable cooling device perferred by in-home growers. Cooling interactive effects were not assessed on a central system as only 2% of existing residences in Vermont have central air conditioning, per the previously referenced NMR report. Additionally, it was assumed that the measure replacement scenario would result in negligble impacts to any fans or other ventilation system as air movement across plants aid in their health and growth and would not be impacted by the lighting.

[3] The default or unknown interactive effects assume that 23.2% of customers will use some sort of mechanical cooling. This value is sourced from "Energy Trust of Oregon Residential Grow Light Research", Evergreen Economics, May 2018.

[4] The default or unknown quantity of plant production cycles is assumed to be 3.3 cycles per year. This value is sourced from survey respondents of the "Energy Trust of Oregon Residential Grow Light Research", Evergreen Economics, May 2018. It respresents a weighted average from survey respondents, taking into account quantity of cycles and location, as 100% of interior operations will leverage lights; 0% of exterior operations; and 47% growing in greenhouses will use lights

[5] The lighting run hours per cycle is sourced from "Energy Trusy of Oregon Residential Grow Light Research", Evergreen Economics, May 2018. The run hours per day and length in weeks per plant growth stage was sourced as a weighted average of survey respondents. The results were as follows; 10.3 hours per day for the seedling stage which runs on average for 1.5 weeks; 15.6 hours per day for the vegetative stage which runs on average 3.5 weeks; and 15.8 hours per day for the flowering stage which runs on average for 8 weeks.

Flexible Load Management: Electric Vehicle Supply Equipment

Measure Number: RS-MSC-FLMEVS a
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Residential & Multifamily
End Use: Miscellaneous

Update Summary

This is version 1.0 of the characterization.

Referenced Documents

- GMP eCharger Pilot Update 2020
- ISO NE Update on the 2020 Transportation Electrification 2019
- Pages from GMPExhibits
- VELCO 2020 Long-Term System Load
- EVT TRM FLM EVSE Analysis Dec 2021

Description

Electric vehicle supply equipment load flexibility is enabled through controls and supporting hardware that safely disconnect charging of vehicle from grid. Electric vehicle charging is a large demand on a residential's load profile and disconnecting this load during peak periods can provide benefits for the grid.This measure accounts for the demand that can be reduced by disconnecting the charger during the peak periods. The resource must be capable of being connected to an active distribution utility grid-management program such that it can be dispatched during peak times.

Installation of controls is considered a Market Opportunity activity.

Program Type

Calculation Type: Market Opportunity
Program Delivery/Implementation Type:v Downstream

Baseline Efficiencies

Baseline is an electric vehicle supply equipment without control equipment and therefore no grid interactivity.

Efficient Equipment

The efficient condition is defined as electric vehicle supply equipment that either had controls enabled or has been retrofitted with controls and necessary supporting hardware that would enable a distribution utility to control its electric load draw. It has the ability to be grid interactive, meaning it's capabable of providing grid balancing services as determined by the distribution utility.

Algorithms

Electric Demand Savings

No electric demand savings are claimed. Data will be collected and shared over 2021-2023 to understand if and how distribution utilities are able to utilize this resource. EVT is committed to collecting the necessary data to understand any demand savings and their seasonal coincidence factors.

Flexible Load kW

As defined by PIP #125 Flexible Load Management (FLM), **Flexible Load kW** is the maximum amount of demand reduction available to be controlled for at least one hour between 4pm and 10pm on any day in any season, measured and reported in units of kW.

At best, controls could allow complete shutoff of electric vehicle supply equipment for any given hour and therefore Flexible Load kW is estimated by considering the typical power draw of an electric vehicle charger during the hours between 4pm and 10pm.

Electric Vehicle Supply Equipment	Measure Code	Item Code	Flexible Load kW Credit (kW)[1]
Level 2 Charger with Controller	FLMEQPEV	FLM-RESEVSE1	0.49

Electric Energy Savings

No energy savings are claimed, or necessarily expected. EVT is committed to tracking and reporting kWh impacts for participants and will make appropriate revisions to claimed energy impact when more is understood.

Fossil Fuel Savings

None.

Load Shapes

This is a placeholder loadshape until data collection can inform a more appropriate choice.

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%

Net Savings Factors

Measures

FLMEQPEV	Flexible Load Management - Electric Vehicle Charging Stations

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	FLMEQPEV	1.00	1.00

Lifetimes

The expected measure life for the EV charger is assumed to be 10 years[2]

Measure Cost

The assumed incremental cost of a charger with a controller is $227.15.[3]

Footnotes

[1] The flexible kW calculation is derived from reviewing three sources of New England sourced EVSE controller analysis, which include studies from Green Mountain Power, VELCO, and ISO-NE. These analyses can be found in the analysis file: EVT TRM FLM EVSE Analysis Dec 2021.xlsx and in the referenced documents of this measure characterization.

[2] Based on Northwest Power and Conservation Council, Regional Technical Forum workbook for Level 2 Electric Vehicle Charger version 1.1. approved May 2019. https://rtf.nwcouncil.org/measure/level-2-electric-vehicle-charger. Other sources reviewed can be found on the Measure Life tab of the analysis document: EVT TRM FLM EVSE Analysis Dec 2021.xlsx

[3] A review of nine electric vehicle chargers that are either remote accessed or not remote accessed are reviewed. The average cost of a charger with remote access is subtracted from the average cost for a charger without remote access. Analysis can be found on Cost tab of EVT TRM FLM EVSE Analysis Dec 2021.xlsx

Low Flow Toilet

Measure Number: VI-M-1 a
Portfolio: EVT TRM Portfolio 2018-01
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Residential New Construction
End Use: Miscellaneous

Update Summary

New measure

Referenced Documents

- U.S. Census Bureau_ACS Table DP04 Vermont_2015
- DeOreo_Residential End Uses of Water Study 2013 Update_2014
- EPA_WaterSense Labeled Products_Dec 2017
- WRF_Residential End Uses of Water Exec Summary_Apr 2016
- City of Fort Collins_Green Building Practice Summary_Mar 2011

Description

This measure characterizes the installation of a WaterSense labeled toilet in a new home.

Algorithms

Water Savings

Using the default assumptions provided below, water savings are:

$\Delta CCF = ((1.38 - 1.28) \times 5 \times 2.33 / 2.5 \times 365) / 748 = 0.23$ CCF

ΔCCF	$= ((GPF_{base} - GPF_{low}) \times \# flushes \times \# people / toilets/home \times usedays/year) / 748$

Where:

# flushes	=	Average number of toilet flushes per person per day = 5[1]
# people	=	Average number of people per household = 2.33[2]
ΔCCF	=	Gross customer annual water savings for the measure
748	=	Constant to convert from gallons to CCF
GPF_{base}	=	Gallons per flush (gpf) of baseline toilet = 1.38 gpf[3]
GPF_{low}	=	Flow rate (gpm) of low flow toilet = 1.28 gpf[4]
toilets/home	=	Average number of toilets per household = 2.5[5]
usedays/year	=	Days toilet is used per year = 365

Baseline Efficiencies

The baseline is a toilet that uses 1.38 gallons per flush (gpf).[3]

Efficient Equipment

The efficient condition is a toilet that uses 1.28 gpf.[4]

Load Shapes

There are no loadshapes associated with this measure.

Net Savings Factors

Measures

WATLFTLT	Low flow toilet

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	WATLFTLT	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

The measure life is assumed to be 30 years.[6]

Measure Cost

The incremental cost difference between a standard toilet and a WaterSense toilet is assumed to be $0.[7]

Footnotes

[1] Water Research Foundation, "Residential End Uses of Water, Version 2: Executive Report," April 2016, page 9.

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[3] Weighted average using a total of 542 federal standard toilets (1.6 gpf, established by the Energy Policy Act of 1992) and a total of 1,070 WaterSense toilets (1.28 gpf) available on Home Depot and Lowe's websites during a January 2018 review.

[4] Efficient toilet flow rate is the average flow rate of tank-type, single-flush toilets on the WaterSense Labeled Products list as of December 4, 2017.

See file EPA_WaterSense Labeled Products_Dec 2017.xlsx.

[5] Average number of toilets per home from the Water Research Foundation, "Residential End Uses of Water Study 2013 Update," 2014, page 128.

[6] Toilet lifetime from Wisdom Blake Home Inspections: http://www.metrohome.us/information_kit_files/life.pdf and ATD Home Inspection: http://www.atdhomeinspection.com/advice/average-product-life/ is 50 years. EVT caps measure lifetimes at 30 years.

[7] Measure cost assumption from City of Fort Collins, "Green Building Practice Summary," March 21, 2011, page 2. The document states "Information from the EPA WaterSense web site: WaterSense® labeled toilets are not more expensive than regular toilets. MaP testing results have shown no correlation between price and performance. Prices for toilets can range from less than $100 to more than $1,000. Much of the variability in price is due to style, not functional design."

Maple Sap Vacuum Pump VFD

Measure Number: I-A-10 b
Portfolio: EVT TRM Portfolio 2017-11
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Motors

Update Summary

- Due to the relatively low volume of measures prescriptively implemented, this measure was not opted for a major algorithm overhaul, but rather an update based on aggregate savings claims and cost data from prior custom projects. The original characterization of this measure claimed savings based on an average from custom pilot projects implemented from 2010-2012.
- I drilled down on the measure savings and costs from these prior custom projects, updating the existing aggregates from a per unit basis to a per horsepower basis. I uploaded a new analysis workbook reflecting savings and costs on both a per unit and per horsepower basis.

Referenced Documents

- Maple-Sap-VFD-Analysis_v3

Description

The measure is a VFD attached to the vacuum pump in a maple sap extraction system that allows operators to manage system pressure by reducing pump speed rather than by using an inefficient method such as a differential pressure relief valve.

Estimated Measure Impacts

	Average Annual MWH Savings per unit	Average number of measures per year[1]	Average Annual MWH Savings per year
Maple Sap Vacuum Pump VFD	1.81	18	32.52

Algorithms

Electric Demand Savings

ΔkW	= kW/HP x HP

Symbol Table

Electric Energy Savings

ΔkWh	= kWh/HP x HP

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer average annual kWh savings for the measure
HP	=	horsepower of the motor to which the VFD is applied
kW/HP	=	0.12[2]
kWh/HP	=	155[2]

Savings estimates are the average savings claimed per motor horsepower for EVT custom projects in 2010, 2011, and 2012, see Maple Sap VFD_Analysis_v2.xls

Baseline Efficiencies

The baseline reflects a maple sap extraction system without a VFD equipped vacuum pump.

High Efficiency

The high efficiency case is installation and use of a VFD equipped vacuum pump.

Operating Hours

N/A

Load Shapes

112a Maple Sap VFD

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
112	Maple Sap VFD	Active	51.2%	48.8%	0.0%	0.0%	0.0%	0.0%

Net Savings Factors

Measures

MTCSAPVP	Maple Sap Vacuum Pump VFD

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years.

Measure Cost

$159/HP[2]

O&M Cost Adjustments
There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description
There are no fossil-fuel algorithms or default savings for this measure.

Prescriptive Savings Table

Horsepower	Prescriptive Energy Savings (kWh)	Prescriptive Connected Load Reduction (kW)	Incremental Costs ($)
7.5	1,163	0.90	$1,193
10	1,550	1.20	$1,590
15	2,325	1.80	$2,385
20	3,100	2.40	$3,180
25	3,875	3.00	$3,975

Footnotes

[1] Assumes that there will be ~50% more Rx measures per year than the average number of custom measures per year in 2010 and 2011, see Maple Sap VFD_Analysis.xls

[2] Derived from Efficiency Vermont custom data 2010-2011, see Maple Sap VFD_Analysis.xls

Notched V-Belts

Measure Number: I-A-11 a
Portfolio: EVT TRM Portfolio 2018-11
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Motors

Update Summary

New measure

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- USDOE EERE_Motor System Tip-Replace V-Belts with Cogged Belt Drives_Sept 2015
- EVT Cogged V-Belts PPT_McCarran
- USDOE_Ind. Motor Market Opp. Assessment_Dec 2002
- Gates Rubber_Gate Co. Announces New EPDM Molded Notch V-Belts_Jun 2010
- ACEEE_Midstream Cogged V-Belt Pilot Program_2015
- EVT Cogged V-Belt Market Research_McCarran
- EVT_Notched V-Belt_Analysis_Nov 2018
- PGECOHVC144 R1 Cogged V-belts

Description

This measure is the replacement of smooth v-belts with notched v-belts on electric motors in the industrial and commercial sectors that use belt drives. Notched v-belts have slots that run perpendicular to the belt's length, which help reduce the bending resistance of the belt. As a result, they run cooler and have an improved efficiency over standard v-belts. Overall efficiency is dependent on pully size, driven torque, under- or over-belting, and v-belt design and construction. Efficiency for standard v-belts deteriorates over time if slippage occurs because the belt is not periodically re-tensioned. For the purposes of this measure characterization, notched and cogged v-belts are considered identical and the terms can be used interchangeably to describe the type of v-belt.

Baseline Efficiencies

The baseline equipment is smooth v-belts on electric motors in the industrial and commercial sector that use belt drives.

Efficient Equipment

The efficient equipment is the installation of notched v-belts on electric motors in the industrial and commercial sector that use belt drives.

V-belts are usually referred to in the following groups:

- "A" and "B" belts are typically rated for smaller horsepower motors. The "A" belt is 1/2 inch width by 5/16 inch thickness and the "B" belt is larger, 21/32 inch wide and 12/32 inch thick so it can carry more power. V-belts come in a wide variety of lengths where 20 to 100 inches is typical.
- "C" and "D" belts are primarily for larger industrial applications with high power transmission requirements and are approximately 7/8 inches wide.

The notched version of these belts typically have an "X" added to the designation. For example, a typical "A" v-belt is replaced by a notched "AX". Because notched v-belts are more flexible, they work with smaller diameter pulleys and hey have less resistance to bending. Lower bending resistance increases the power transmission efficiency, lowers the waste heat, and allows the belt to last longer than a smooth belt.

Algorithms

Electric Demand Savings

ΔkW	$= kW_{Motor} \times ESF$

Symbol Table

Electric Energy Savings

ΔkWh	$= kWh_{Motor} \times ESF$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for this measure
ΔkWh	=	Gross customer annual kWh savings for this measure
ESF	=	Energy savings factor = 2%[1]
kW_{Motor}	=	Connected load of the motor[2] see table 1 for deemed assumptions
kWh_{Motor}	=	Annual energy consumption of the motor[2] see table 1 for deemed assumptions

Table 1 - Deemed Algorithm Assumptions

Belt Type	Motor Hp Size Range	kW_{Motor}	kWh_{Motor}
Type A	≤ 18 hp	2.630	8,300
Type B	> 18 hp and ≤ 75 hp	18.924	83,548
Type C	> 75 hp and ≤ 150 hp	47.150	266,775

Table 2 - Deemed Energy and Demand Savings

Belt Type	Item Code	ΔkW Savings	ΔkWh Savings
Type A	VBELTA1	0.053	166
Type B	VBELTB2	0.379	1,671
Type C	VBELTC3	0.943	5,336

Load Shapes

44b Indust. 1-shift (8/5) (e.g., comp. air)
45a Indust. 2-shift (16/5) (e.g., comp. air)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
44	Indust. 1-shift (8/5) (e.g., comp. air)	Active	66.6%	0.0%	33.4%	0.0%	0.0%	59.4%
45	Indust. 2-shift (16/5) (e.g., comp. air)	Active	62.4%	4.2%	31.3%	2.1%	95.0%	95.0%

Net Savings Factors

The net savings factors for this measure are detailed below:[3]

Measures

MTRVBELT	Notched v-belt

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	MTRVBELT	0.85	1.00
Upstream - Commercial	6013UPST	MTRVBELT	0.85	1.00

Lifetimes

Notched v-belt lifetime is based on an estimate belt life of 24,000 hours[4]. The lifetime in years vary based on the belt type, designation, and application.

Table 3 - Measure Lifetime

Belt Type	Lifetime (years)
Type A	8
Type B	6
Type C	4

Measure Cost

The incremental cost for this measure is represented in the table below and varies based on the belt type, designation, and application.

Table 4 - Incremental Cost[5]

Belt Type	Incremental Cost
Type A	$5.74
Type B	$8.82
Type C	$14.66

Footnotes

[1] The 2% energy savings factor is sourced from a U.S. DOE Energy Efficiency and Renewable Energy energy savings resource, "Motor System Tip Sheet #5, Replace V-Belts with Cogged or Synchronous Belt Drives", USDOE-EERE, September 2005. This is a relatively conservative estimate as a number of research papers show that notched v-belt energy savings range between 2% and 5% ("Gates Corporation Announces New EPDM Molded Notch V-Belts", The Gates Rubber Co., June 2010; and "A Midstream Cogged V-Belt Pilot Program: Concept and Early Challenges", Seryak et al., ACEEE, 2015)

[2] The average connected load and energy consumption of the impacted motor is sourced from a motor market assessment conducted by the U.S. Department of Energy; "United Stated Industrial Electric Motor Systems Market Opportunity Assessment", U.S. DOE, December 2002 (page B-2)

[3] The net savings factors are sourced from DEER 2014 and the PG&E workpaper, "HVAC Fans Cogged V-belt Replacement, PGECOHVC144, May 2014".

[4] The measure life, in hours, is sourced from DEER 2014 ("DEER2014-EUL-table-update_2014-02-05.xlsx"; Database for Energy Efficiency Resources (DEER))

[5] Incremental cost is sourced from EVT product pricing and research on notched V-belts for type A and B applications. Type C V-belts were interpolated based on the findings for Type A and B belts. For more information, please see "EVT Cogged V-Belt Market Research_McCarran.xlsx" and "EVT Cogged V-Belts PPT_McCarran.pptx"

Milk Vacuum Pump VFD

Measure Number: I-A-5 d
Portfolio: EVT TRM Portfolio 2019-04
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Motors

Update Summary

Updates made to connected load (kW) savings; energy savings (kWh); and incremental costs. Per request from the program implementation team, milk transfer pump VFD savings were removed from the measure characterization. Loadshape, persistance factor, net to gross savings factors, and lifetime all remained the same and were not updated.

Deemed values were originally sourced from a straight average of custom projects from 2003 to 2011. TRM update included incorporating custom projects from 2012 through 2018 into the data set. This increased the data set from 207 projects to 225, a 8.7% increase.

From 2012 through 2018, there were 132 prescriptive projects, or approximately 19 measures incentivized per year. Due to the relatively low participation numbers, opted to keep the measure update similarly low impact. Instead of over-hauling the measure for a prescriptive algorithm approach or a scaled approach using motor horsepower, opted to maintain the same deemed savings approach that was previously used.

Referenced Documents

- EVT_Milk Pump VFD_Analysis_Apr 2019

Description

A milk vacuum pump for a dairy farms operates during the milk harvest and equipment rinsing periods. The vacuum pump creates negative air pressure that draws milk from the cow and transfers it to either a milk receiver jar or for bulk storage. A variable frequency drive (VFD) equipped on a milk vacuum pump is used to reduce pump speed in order to adjust and deliver the amount of vacuum needed in the milk parlor. A VFD offers energy savings for the milk vacuum pump when the pumping needs fall below peak levels. Electricity is saved relative to a system that pumps at a constant rate. A VFD milk vacuum pump typically replaces old equipment when it reaches the end of its useful life.

Algorithms

Milk Vacuum Pump VFD Electric Demand Savings

ΔkW	= 3.06 kW

Symbol Table

Milk Vacuum Pump VFD Electric Energy Savings

ΔkWh	= 8,303 kWh

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer average annual kWh savings for the measure

Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2018, see "EVT_Milk Pump VFD_Analysis_Mar 2019.xls"

Baseline Efficiencies

The baseline case is a non-VFD equipped milk vacuum pump.

While these technologies would be baseline for new construction, farmers typically re-use old equipment when extensively renovating old facilities. New construction due to construction of new facilities is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment. Vermont Commercial and Residential code requirements currently exclude agriculture enterprises from adhering, and as a result, do not stipulate or require VFDs on milk harvest vacuum pumps.

High Efficiency

The efficient case is a milk vacuum pump equipped with a VFD equipped.

Operating Hours

N/A

Load Shapes

Load shapes were developed based on actual data for EVT custom projects installed through the EVT dairy farm program from 2008 through 2011. For more information see; "EVT_Milk Pump VFD_Analysis_Mar 2019.xls". The milk vacuum pump load profile is based on 94 custom projects.

61b Milk Vacuum Pump

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
61	Milk Vacuum Pump	Active	36.9%	30.1%	18.2%	14.8%	63.4%	28.7%

Net Savings Factors

Item Code	DF-XFER-VAC

Measures

MTCDFVFD	Dairy Milk Pump VFD

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Cust Equip Rpl	6013CUST	MTCDFVFD	0.94	1.00
Pres Equip Rpl	6013PRES	MTCDFVFD	1.00	1.00

Persistence

The persistence factor is assumed to be one.[1]

Lifetimes

10 years.

Measure Cost

Milk vacuum pump VFD: $3,998[2]

O&M Cost Adjustments
There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description
There are no fossil fuel algorithms or default values for this measure.

Footnotes

[1] National Grid evaluated persistence in 1999 of VFDs installed in 1995 and estimated a factor of 97%. Given that the discounted value of a 3% degradation in 5 years is minimal, no persistence reduction has been applied.

[2] Values derived from Efficiency Vermont custom data 2003-2018; see, "EVT_Milk Pump VFD_Analysis_Mar 2019.xls"

Comprehensive Thermal Measure

Measure Number: III-F-3 c
Portfolio: EVT TRM Portfolio 2018-12
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Multifamily
End Use: Multiple End Uses

Update Summary

December 2018 - this update aligns TRM content with how the 2018 program and process operates.

Referenced Documents

- MeasureCost_StevePitkin6-15-11
- EVT Multifamily New Construction Minimum Requirements

Description

This measure characterization describes the analytical approach for a package of shell and HVAC measures performed to meet the requirements of the Efficiency Vermont Multifamily New Construction and Major Rehabilitation Program. The program incentivizes projects meeting requirements for one of three tracks: Electric Only, Efficiency Vermont Certified, and High-Performance.

This characterization is intended to capture a high level analytical approach for the program. Typically, all components of an analysis with the exception of incremental cost assignment is performed on a site-specific, custom basis. Thus, the utility of this characterization in relation to project analysis is limited to establishing incremental costs.

Estimated Measure Impacts

Algorithms

Energy and Demand Savings

Energy (kWh and MMBtu) and Demand (kW) savings will be calculated on a custom basis, typically using EVT's QLoss tool. Historically REMRate was employed for analytical purposes, however recent guidance from the program's developers has cautioned against using it to model larger multifamily buildings. To do so confidently, individual units would need to be modeled separately, which is prohibitively expensive for EVT from a resource standpoint. For a fee, REMRate will be used upon customer request, if for example ENERGY STAR certification is being pursued.

Baseline Efficiencies

Vermont's 2015 Residential Building Energy Standards (30 V.S.A. § 51) apply and serve as baseline project requirements, except in instances where 2015 Commercial Building Energy Standards apply. RBES 2015 gives five prescriptive package options to meet compliance. For any project, the relevant baseline as chosen and indicated by the customer is used to estimate impacts. In practice, it has been observed that the majority of customers chose Package 4.

High Efficiency

Minimum program requirements must be met to qualify for incentive (see referenced document EVT Multifamily New Construction Minimum Requirements). Actual project-specific specifications will be used for impact analysis.

Operating Hours

Load Shapes

Custom loadshapes will be used as appropriate and necessary. Typically, however, measures use one of the following default loadshapes.

7a Residential DHW insulation
5b Residential Space heat
11b Residential A/C

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%
11	Residential A/C	Active	6.6%	3.8%	51.1%	38.6%	0.0%	16.0%

Net Savings Factors

Measures

TSHCOMPH	Comprehensive Thermal Measure REMRate Calculated Heating
TSHCOMPC	Comprehensive Thermal Measure REMRate Calculated Cooling
HWECOMP1	Comprehensive Thermal Measure REMRate Calculated DHW

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Persistence

The persistence factor is assumed to be one.

Lifetimes

(Consistent with lifetime estimates used by Efficiency Vermont in the state screening tool.)

Heating Savings: 25 years

AC Savings: 15 years

DHW Savings: 15 years

Analysis period is the same as the lifetime.

Measure Cost

EVT Certified Comprehensive Thermal Package

	Incremental Cost Assumption Per Unit					
Number of Units	1-5	6-10	11-15	16-20	21-25	26+
Heating Savings (heating system and shell upgrades)	$ 2,554	$2,159	$1,764	$1,369	$974	$500
Air Conditioning Savings (AC systems)	$300	$270	$240	$211	$181	$145

DHW Savings	$0	$0	$0	$0	$0	$0
Total Cost (with cooling)	$2,854	$2,429	$2,004	$1,580	$1,155	$731
Total Cost (without cooling)	$2,554	$2,159	$1,764	$1,369	$974	$500

Notes:

1. Incremental costs used are based on the least expensive options provided, since this is the cost required to meet approved efficiency levels. Any costs associated with alternate decisions that the participant may make to achieve similar efficiency levels are not be included.

2. DHW Savings has a zero measure cost since there is no increment in cost between an indirect tank off a 84% boiler or an indirect tank off a 94% boiler. The incremental cost of the boiler itself is captured in the heating savings.

3. Incremental costs were modeled using a 5 unit and a 31 unit building and cost estimates were provided by Steve Pitkin, construction project manager and cost estimator. See 'MeasureCost_StevePitkin6-15-11.xls' for more information. Clearly the incremental cost per unit is much higher for smaller buildings than larger buildings so the per unit cost assumptions are extrapolated for different building sizes assuming a linear relationship.

High-Performance Incremental Costs

	Incremental Cost Assumption (EVT Certified to High-Performance) per unit					
Number of Units	1-5	6-10	11-15	16-20	21-25	26+
Staged 95% AFUE gas boilers	$0	$1	$2	$4	$5	$6
Staged 91% AFUE oil boilers	$840	$698	$555	$413	$271	$128
Staged 85% AFUE pellet boilers	$1,760	$1,711	$1,661	$1,612	$1,562	$1,513
Indirect DHW off a 95% gas boiler	$0	$0	$0	$0	$0	$0
Indirect DHW off a 91% oil boiler	$0	$0	$0	$0	$0	$0
Central AC - 15 SEER, 12.5 EER (CEE T2)	$220	$187	$154	$121	$88	$55
3 ACH50 (0.4 cfm50/sq ft)	$767	$679	$591	$502	$414	$325

These costs will be included above the EVT Certified level costs if these measures are included in the project.

O&M Cost Adjustments

Fossil Fuel Description

Footnotes

ENERGY STAR Retail Products Platform

Measure Number: RS-MLT-ESRPP d
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Multiple End Uses

Update Summary

Updates to:

- Remove v1 ENERGY STAR Air Cleaners (only v2 now supported)
- Updates to Refrigerators - Basic is now ESTAR and ESTAR Most Efficient, Advanced is Emerging Technology Award which are units with natural refrigerant - and therefore GHG savings are assigned.
- Updates to Freezers- Basic is ESTAR and Advanced is ESTAR Most Efficient and Emerging Technology Award. Those qualified as ETA are units with natural refrigerant - and therefore GHG savings are assigned.

Referenced Documents

- epa-rpp-product-analysis-evt-2017
- DOE Energy Conservation Standards for Dehumidifiers, July 2012
- 2019 Clothes Dryer RPP Calculations
- 2019 Clothes Washer RPP Calculations
- 2019-energy-star-certified-televisions-analysis
- Most Efficient Room AC_ESRPP
- Air Cleaner ESRPP
- EVT Dehumidifer Analysis nov 2019- final
- 2021 ESRPP Refrigerators
- 2021 ESRPP Freezers

Description

This measure describes the ENERGY STAR Retail Products Platform (ESRPP), an initiative facilitated by the U.S. Environmental Protection Agency. This program will engage retailers through midstream/upstream incentive payments to increase the demand for and supply of the most energy efficient residential plug-load and appliance products on the market, driving greater sales of select ENERGY STAR certified products to customers. With a combination of incentives and engagement, retailers will assort, stock, and promote more energy efficient models than they would have absent the program. Covered products include sound bars, freezers, refrigerators, portable dehumidifiers, clothes dryers, clothes washers, room air cleaners, and room air conditioners. This measure applies to Time of Sale program delivery.

Program Type

Calculation Type: Time of Sale

Program Delivery/Implementation Type: Midstream

Baseline Efficiencies

The baseline and efficient cases for each product are listed in the table below.

Product	Baseline Efficiency	High Efficiency
ENERGY STAR Sound Bars	Weighted average of electric energy consumption[1] for both non-ENERGY STAR and ENERGY STAR models	50% more efficient[2] than ENERGY STAR Version 3.0 specification, effective May 1, 2013
ENERGY STAR and ENERGY STAR Most Efficient Televisions	Average of non ENERGY STAR units from California Appliance Database.	ENERGY STAR Version 8.0, effective March 1, 2019 and ENERGY STAR Most Efficient.
Freezers (Basic)	Federal standard, effective September 15, 2014	ENERGY STAR Version 5.0 specification, effective September 15, 2014
Freezers (Advanced)	Federal standard, effective September 15, 2014	ENERGY STAR Most Efficient or ENERGY STAR Emerging Technology Award (with Natural Refrigerant)
Refrigerators (Basic)	Federal standard, effective September 15, 2014	ENERGY STAR Version 5.0 specification, effective September 15, 2014 and ENERGY STAR Most Efficient.
Refrigerators (Advanced)	Federal standard, effective September 15, 2014	ENERGY STAR Emerging Technology Award (with Natural Refrigerant)
Clothes Dryer (Basic)	The baseline combined energy factor (CEF) was derived in the ENERGY STAR Version 1.0 analysis by multiplying 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements.	ENERGY STAR Version 1.0 specification, effective January 1, 2015
Clothes Dryer (Advanced)	As above	ENERGY STAR Most Efficient criteria (weighted by 2018-2019 ESRPP sales average of Hybrid and Full Heat Pump is used).
Clothes Washers (Basic)	Federal standard, effective January 1, 2018	ENERGY STAR Version 8.0 specification, effective February 5, 2018.
Clothes Washers (Advanced)	As above	ENERGY STAR Most Efficient.
ENERGY STAR Room Air Cleaners	Room air cleaners that do not meet ENERGY STAR efficiency requirements	ENERGY STAR V2.0 units effective July 1, 2020.
Room Air Conditioners (Basic)	Federal standard, effective June 1, 2014	ENERGY STAR Version 4.0 specification, effective October 26, 2015.
Room Air Conditioners (Advanced)	As above	ENERGY STAR Most Efficient.
Portable Dehumidifiers (Basic)	Federal standard, effective June 1, 2019	ENERGY STAR Version 5.0 specification, effective October 31, 2019.
Portable Dehumidifiers (Advanced)	As above	ENERGY STAR Most Efficient.

Efficient Equipment

See 'Baseline & Efficient" table within "Baseline Efficiencies" section.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh/HOURS

Symbol Table

Electric Energy Savings

The baseline and energy efficient kWh consumption and the kWh and kW savings for each product are provided in the table below.[5]

Product	kWh_{BASE}	kWh_{EE}	ΔkWh	ΔkW	ΔGHG	Item Code
ENERGY STAR +50% Sound Bars	48.7	24.7	24.0	0.00274	N/A	ESRPP-SBAR
ENERGY STAR Television	See '2019 Energy Star Certified Televisions Analysis.xls'.		37.8	0.01993	N/A	ESRPP-TVES
ENERGY STAR Most Efficient Television	See '2019 Energy Star Certified Televisions Analysis.xls'.		55.6	0.02931	N/A	ESRPP-TVME
Freezers (Basic)[6]	424.2	380.1	44.2	0.0052	N/A	ESRPP-FRZ2
Freezers (Advanced) - ENERGY STAR Most Efficient	479.3	393.5	85.8	0.0101	N/A	ESRPP-FRZ5
Freezers (Advanced) - ENERGY STAR Emerging Technology Award	479.3	393.5	85.8	0.0101	8.86	ESRPP-FRZ6
Refrigerators (Basic)[7] ENERGY STAR and ENERGY STAR Most Efficient	544.1	492.9	51.2	0.0060	N/A	ESRPP-RFRT1
Refrigerators (Advanced) ENERGY STAR Emerging Technology Award	743.4	670.8	72.6	0.0086	8.86	ESRPP-RFRAD
Clothes Dryer (Basic)	See spreadsheet '2019 Clothes Dryer RPP Calculations.xlsx'		195	0.6045	N/A	ESRPP-CD1
Clothes Dryer (Advanced)	See spreadsheet '2019 Clothes Dryer RPP Calculations.xlsx'		427	1.3263	N/A	ESRPP-CDME
Clothes Washers (Basic)	See spreadsheet '2019 Clothes Washer RPP Calculations.xlsx'		134.6	0.418	N/A	ESRPP-CWT1
Clothes Washers (Advanced)	See spreadsheet '2019 Clothes Washer RPP Calculations.xlsx'		158.4	0.492	N/A	ESRPP-CWME
ENERGY STAR v2 Room Air Cleaners	1086	285	801	0.1371	N/A	ESRPP-RPUR4
Room Air Conditioners (Basic)	114.7	104.0	10.7	0.07589	N/A	ESRPP-RAC
Room Air Conditioners (Advanced)	See "evt-energy-star-room-ac-analysis-2020.xlsx'		52.2	0.37	N/A	ESRPP-RACME
Portable Dehumidifiers (Basic)	See spreadsheet 'EVT Dehumidifier Analysis Nov 2019.xlsx'		99	0.061	N/A	ESRPP-DHUM1
Portable Dehumidifiers (Advanced)	See spreadsheet 'EVT Dehumidifier Analysis Nov 2019.xlsx'		139	0.085	N/A	ESRPP-DHUM2

ΔkWh	= kWh_{Base} - kWh_{EE}

Symbol Table

Fossil Fuel Savings

The prescriptive annual MMBtu savings per unit for clothes dryers are:[8]

	Total MMBtu	NG	LP	Oil	Wood
ENERGY STAR Clothes Dryer	-0.0300	-0.003	-0.006	-0.010	-0.011
ENERGY STAR Most Efficient Clothes Dryer	0.784	0.083	0.154	0.253	0.294

The prescriptive annual MMBtu savings per unit for clothes washers are:[9]

	NG	LP	Oil
ENERGY STAR Clothes Washers	0.10	0.12	0.04
ENERGY STAR Most Efficient Clothes Washers	0.22	0.25	0.13

Water Savings

The prescriptive annual Water savings per unit for clothes washers are:

ENERGY STAR Clothes Washers - 2.4 CCF

ENERGY STAR Most Efficient Clothes Washers - 3.5 CCF

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

HOURS = Average hours of use per year; see table below. Except where otherwise noted, see standalone measure for references.

Product	HOURS
Sound Bars	8,760
Televisions	1,898[3]
Freezers	8,477
Refrigerators	8,477
Clothes Dryers	322
Clothes Washers	322
Room Air Cleaners	5,840[4]
Room Air Conditioners	141
Dehumidifiers	1,632

kWh_{Base} = Baseline kWh consumption per year

kWh_{EE} = Energy efficient kWh consumption per year

Load Shapes

4b Residential Refrigerator
9a Residential Clothes Washer
73a Residential - Dehumidifier
94a Efficient Television
118a Room Air Cleaner
99b Room Air Conditioning

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8%	33.0%	17.1%	19.1%	79.6%	100.0%
9	Residential Clothes Washer	Active	42.0%	28.8%	16.9%	12.3%	4.4%	3.3%
73	Residential - Dehumidifier	Active	15.9%	17.5%	31.7%	34.9%	0.0%	35.3%

94	Efficient Television	Active	48.0%	19.0%	24.0%	9.0%	22.0%	17.0%
118	Room Air Cleaner	Active	31.7%	34.9%	15.9%	17.5%	66.6%	66.6%
99	Room Air Conditioning	Active	0.7%	2.8%	53.3%	43.2%	0.0%	11.9%

Net Savings Factors

Measures

RFRESFZP	Energy star freezer
CKLESWRP	Energy Star Clothes Washer
RFRESRRP	Energy star refrigerator
ACEESARP	Energy Star room AC
ACEDEHUM	Energy Star Dehumidifier
EQPTLVSN	Efficient Televisions
RFRESRT2	Tier 2 refrigerator
CKLC2WRP	Energy Star clothes washer CEE Tier 2
CKLESDRY	Energy Star Clothes Dryer
CKLESETA	Energy Star Most Efficient Clothes Dryer
EQPTVSBR	ENERGY STAR Sound Bars
ACEESRAC	ENERGY STAR Room Air Cleaner
ACEDHUME	ENERGY STAR Residential Dehumidifier Most Efficient tier

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	RFRESFZP	0.67	1.33
Efficient Products - Residential	6032EPEP	CKLESWRP	0.50	1.00
Efficient Products - Residential	6032EPEP	RFRESRRP	0.50	1.00
Efficient Products - Residential	6032EPEP	ACEESARP	0.67	1.33
Efficient Products - Residential	6032EPEP	ACEDEHUM	0.77	1.00
Efficient Products - Residential	6032EPEP	EQPTLVSN	0.90	1.10
Efficient Products - Residential	6032EPEP	RFRESRT2	0.90	1.00
Efficient Products - Residential	6032EPEP	CKLC2WRP	0.50	1.00
Efficient Products - Residential	6032EPEP	CKLESDRY	0.90	1.10
Efficient Products - Residential	6032EPEP	CKLESETA	1.00	1.20
Efficient Products - Residential	6032EPEP	EQPTVSBR	0.90	1.10
Efficient Products - Residential	6032EPEP	ACEESRAC	0.95	1.05
Efficient Products - Residential	6032EPEP	ACEDHUME	0.95	1.05

Lifetimes

The measure lifetime for each product is provided in the table below. Analysis period is the same as the lifetime. Except where otherwise noted, see standalone measure for references.

Product	Measure Life
Sound Bars	4.4 years[10]
Televisions	6 years
Freezers	17 years
Refrigerators	17 years
Clothes Dryers	12 years
Clothes Washers	14 years
Room Air Cleaners	9 years[11]
Room Air Conditioners	10.5 years
Dehumidifiers	12 years

Persistence

The persistence factor is assumed to be one.

Measure Cost

The per-unit incremental cost for each product is provided in the table below. Except where otherwise noted, see standalone measure for references.

Product	Incremental Cost
ENERGY STAR Sound Bars [12]	$0
ENERGY STAR Televisions	$0
Freezers (Basic)	$9
Freezers (Advanced)	$40
Refrigerators (Basic)	$12
Refrigerators (Advanced)	$21
Clothes Dryers (Basic)	$61
Clothes Dryers (Advanced)	$412
Clothes Washers (Basic)	$124
Clothes Washers (Advanced)	$170
ENERGY STAR Room Air Cleaners[13]	$56
Room Air Conditioners (Basic)	$50
Room Air Conditioners (Advanced)	$139
Dehumidifiers (Basic)	$10
Dehumidifiers (Advanced)	$75

Footnotes

[1] Baseline electric energy consumption based on information from a 2014 Fraunhofer Center for Sustainable Energy System study titled "Energy Consumption of Consumer Electronics in US Households." See file EPA RPP Analysis_EVT_2017.xlsx for baseline efficiency calculation. Due to the high market penetration of ENERGY STAR certified soundbars, a weighted average of the unit energy consumption of both non-ENERGY STAR (20% of market) and ENERGY STAR (80% of market) models was calculated to accurately provide savings estimates for the market.

[2] This measure assumes a more stringent requirement than ENERGY STAR Version 3.0. The more stringent requirement was developed by decreasing the power requirements and increasing the efficiency requirement by 50%. See file EPA RPP Analysis_EVT_2017.xlsx for assumptions included in high efficiency requirement.

[3] Based on 5.2 hours per day on mode. See "Efficient Televisions" measure for details.

[4] Based on 16 hours of use per day, 365 days per year

[5] See file EPA RPP Analysis_EVT_2017.xlsx for kWh consumption and savings values for sound bars, freezers, room air cleaners, and ENERGY STAR room air conditioners. For Clothes Dryer, Clothes Washers, Refrigerators, Dehumidifiers and Most Efficient Room AC see downstream measures under Efficient Products program for savings algorithms and assumptions. Clothes Dryer, Clothes Washers, Refrigerators, Dehumidifiers and Most Efficient Room AC have seperate analysis workbooks attached.

[6] See '2021 ESRPP Freezers.xls'

[7] See '2021 ESRPP Refrigerators.xlsx'

[8] See '2019 Clothes Dryer RPP Calculations.xlsx' for fossil fuel savings analysis.

[9] See '2019 Clothes Washer RPP Calculations.xlsx' for fossil fuel savings analysis.

[10] Sound bar lifetime is lifetime for video and compact audio products from file 'EPA RPP Analysis_EVT_2017.xlsx'.

[11] Room air cleaner lifetime from file 'EPA RPP Analysis_EVT_2017.xlsx'.

[12] Incremental cost assumption provided in file 'EPA RPP Analysis_EVT_2017.xlsx'.

[13] Assumptions provided in 2015 *ESRPP* Product Portfolio Analysis spreadsheet; From EPA.

Home Energy Kit

Measure Number: RS-MLT-KIT e
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Existing Homes
End Use: Multiple End Uses

Update Summary

June 2021 Update Summary:

Included three new kit options as Energy Savings Kits for VPPSA customers (Jacksonville, Barton and Ludlow utilities only) as part of the Tailored Communities effort.

Corrected the electric DHW % to 25%.

Referenced Documents

- RLW FCM Demand Impacts Standards Development
- DEER2014-EUL-table-update_2014-02-05.xlsx
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- UMPChapter21-residential-lighting-evaluation-protocol
- Lockeed Martin Energy Solutions nyserda_powerstrip_report
- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Navigant_energySMART Energy Savings Kits_Apr 2016
- Schultdt_Energy Related Water Fixture Measurements_2008
- CalPlug_Tier2_APS_Evaluation
- Cadmus_Process Evaluation Report PPL Electric Program Year 5_Nov 2014
- 2021-2023 EVT Lamp Analysis
- NMR_VT SF Existing Homes Onsite Report - FINAL 072018
- EVT_Home Energy Kit_Analysis_Feb 2021
- EVT_Home Energy Kit_Analysis_Jun 2021

Description

This measure applies to Home Energy Kits, which consist of a number of residential products designed to save energy. The kits are provided to customers through the following avenues:

- Bulk orders to foodbanks to be dispersed and handed out to interested customers.
- Bulk mail order to customers who participate in programs such as Home Energy Visits and Energy Choices and express interest in a home energy kit. Kits will also be distributed to past program participants, such as those who visited the Home Ownership Center.
- Event giveaways
- Online ordering or customers who contact customer service and expressed interest in a kit.

This measure is characterized for 9 distinct types of kits, labeled: Whole Home Energy Kit 1 & 2; Audit Kit 1 & 2; 2021 Kit 1 & 2; and kits provided to VPPSA customers through the tailored communities effot, Whole Home Efficiency Kit, Water Efficiency Kit, and Smart Connected Lighting Kit. EVT will communicate with the potential kit recepients to find which kit best suits their needs and use their discretion accordingly when choosing which of the four to send to the customer.

Kits consist of a combination of the following products: 5.5W, 9W, 11W, and 15W, CEE Tier 1 omnidirectional LED bulbs; 9W, CEE Tier 1 directional LED bulb; Tier 1 advanced power strips; faucet aerators with a flow rate of 1.0 and 1.5 gallons per minute (gpm); low-flow showerheads with a flow rate of 1.5 gpm with an integrated thermostatically-initiated shower restriction valve; and pipe wrap insulation for an uninsulated 3/4" pipe. There are additional 'Do-It-Yourself' (DIY) weatherization products included in Audit Kit 1; however, energy savings are not being claimed for these measures. The DIY products are; foam board insulation, weatherstripping, acrylic caulk, and spray foam insulation. Additionally, technologies included in the kits provided to VPPSA customers, like LED nightlights, WiFi controlled smart outlets, and motion occupancy sensors do not have associated energy savings claims. See savings tables for product mixes of the six kit options for more detail.

Program Type

Calculation Type: Market Opportunity: Time of Sale

Program Delivery/Implementation Type: Efficiency Kits

Baseline Efficiencies

For CEE Tier 1 LED bulbs, the baseline is an weighted average market baseline, comprised of a mix of CFLs, LEDs, and EISA-compliant incandescent and halogen bulbs. Federal legislation stemming from the Energy Independence and Security Act of 2007 began the phasing out of omnidirectional incandescent bulbs. From 2012, 100W incandescents could no longer be manufactured, followed by restrictions on 75W in 2013 and 60W/40W in 2014. Additionally, an EISA backstop provision was included that would require replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. However, in December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that this more stringent standard was not economically justified. The natural growth of LED market share however, has and will continue to grow over the lifetime of the LED measures installed. Therefore a forecast of the baseline growth of LED has been developed, based upon historical growth rates provided via CREED LightTracker data for no-program states, and review of projections provided by the Department of Energy. This baseline forecast is used to estimate a weighted average baseline wattage for the next three years, and also used to estimate how replacement lamps would change over the lifetime of the LED. A single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings.

For Tier 1 advanced power strips, the baseline is a standard power strip that does not control any of the connected loads.

For low-flow faucet aerators, the baseline is a standard faucet aerator with a flow rate of 2.2 gpm. Savings assumptions include a 0.83 throttling factor[1] for baseline faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 1.83 gpm.

For low-flow showerheads, the baseline is a standard showerhead with a flow rate of 2.5 gpm, with no restriction valve in place.

For pipe wrap insulation, the baseline is an uninsulated domestic hot water pipe.

Efficient Equipment

The efficient equipment is a Home Energy Kit consisting of a combination of the following products: 5.5W, CEE Tier 1 omnidirectional LED bulbs; 9W, CEE Tier 1 omnidirectional LED bulbs; 11W, CEE Tier 1 omnidirectional LED bulbs; 15W, CEE Tier 1 omnidirectional LED bulbs; 9W, CEE Tier 1 directional LED bulbs; Tier 1 advanced power strips, faucet aerators with a flow rate of 1.5 gallons per minute (gpm); faucet aerators with a flow rate of 1.0 gpm; low-flow showerheads with a flow rate of 1.5 gpm and with a thermostatically-initiated shower restriction valve; and 3/4" pipe wrap insulation. Savings assumptions for faucet aerators include a 0.95 throttling factor[1] for new faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 0.95 gpm. The additional DIY weatherization products, as well as the LED nightlight, WiFi controlled smart outlet, and motion occupancy sensors were not included in the listing of efficient equipment as energy savings are not being claimed for those items.

Baseline Adjustment

The natural growth of LED market share, has and will continue to grow over the lifetime of the LED measures installed. Therefore a forecast of the baseline growth of LED lamps has been developed, based upon historical growth rates provided via CREED LightTracker data for no-program states, and review of projections provided by the Department of Energy.

This forecast is used to estimate how baseline replacement lamps would change over the lifetime of the LED fixture. A single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. The appropriate adjustments as a percentage of the base year savings for each fixture type are provided in the table below.

The following table shows the calculated adjustments for the five LED bulb products included in the various kit options; a 40-watt equivalent, omnidirectional, 5.5-watt LED bulb; a 60-watt equivalent, omnidirectional, 9-watt LED bulb; a 75-watt equivalent, omnidirectional, 11-watt LED bulb; a 100-watt equivalent, omnidirectional, 15-watt LED bulb; and a 65-watt equivalent, directional, 9-watt LED bulb.[2]

Lamp Type	LED (Watts)	Bulb Wattages Assumed in Calculation		
		Base 2021 (Watts)	Base 2022 (Watts)	Base 2023 (Watts)
Omnidirectional	5.5	14.7	14.0	13.2
	9.0	24.1	22.9	21.6
	11.0	29.4	27.9	26.4
	15.0	40.5	38.4	36.3
Directional	9.0	16.7	16.2	15.7

Algorithms

Electric Demand Savings

ΔkW_{LED}	$= SaveDemand_{LED} \times ISR_{LED} \times Num_{LED}$
ΔkW_{APS}	$= \Delta kWh_{APS} / HOURS_{APS}$
$\Delta kW_{Aerator}$	$= \Delta kWh_{Aerator} / HOURS_{DHW\_Conserve}$
$\Delta kW_{Showerhead}$	$= \Delta kWh_{Showerhead} / HOURS_{DHW\_Conserve}$
$\Delta kW_{Pipe\ Wrap}$	$= \Delta kWh_{Pipe\ Wrap} / 8,760$

Symbol Table

Electric Energy Savings

Electric Energy and Demand Savings

Whole Home Kit 1						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 2 bulbs)	0.02710	26.7	0.02490	24.5	0.02261	22.3
CEE Tier 1, Omnidirectional 15W LED Bulb (total for 2 bulbs)	0.04580	45.1	0.04209	41.5	0.03822	37.7
Tier 1 Advanced Power Strip	0.00416	33.5	0.00416	33.5	0.00416	33.5
1.0 GPM Faucet Aerator	0.00560	19.2	0.00560	19.2	0.00560	19.2
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.01954	67.0	0.01954	67.0	0.01954	67.0
Whole Home Kit 1 Total	0.10219	191.4	0.09628	185.6	0.09012	179.5

Whole Home Kit 2						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 3 bulbs)	0.04065	40.1	0.03735	36.8	0.03391	33.4
CEE Tier 1, Omnidirectional 15W LED Bulb (total for 3 bulbs)	0.06870	67.7	0.06313	62.2	0.05732	56.5
Tier 1 Advanced Power Strip	0.00416	33.5	0.00416	33.5	0.00416	33.5
CEE Tier 1, Directional 9W LED Bulb (total for 2 bulbs)	0.01379	13.6	0.01292	12.7	0.01203	11.9
Whole Home Kit 2 Total	0.12729	154.8	0.11755	145.2	0.10743	135.2

Audit Kit 1						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 4 bulbs)	0.05420	53.4	0.04980	49.1	0.04522	44.6
Foam Insulation	N/A	N/A	N/A	N/A	N/A	N/A
Pipe Wrap Insulation (3/4")	0.00081	7.1	0.00081	7.1	0.00081	7.1
Weatherstripping	N/A	N/A	N/A	N/A	N/A	N/A
Acrylic Caulk	N/A	N/A	N/A	N/A	N/A	N/A
Spray Foam Insulation	N/A	N/A	N/A	N/A	N/A	N/A
1.0 GPM Faucet Aerator	0.00560	19.2	0.00560	19.2	0.00560	19.2
Audit Kit 1 Total	0.06061	79.7	0.05621	75.4	0.05163	70.9

Audit Kit 2						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 4 bulbs)	0.05420	53.4	0.04980	49.1	0.04522	44.6
1.5 GPM Faucet Aerator	0.00128	4.4	0.00128	4.4	0.00128	4.4
1.0 GPM Faucet Aerator	0.00560	19.2	0.00560	19.2	0.00560	19.2
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.01954	67.0	0.01954	67.0	0.01954	67.0
Audit Kit 2 Total	0.08062	143.9	0.07622	139.6	0.07163	135.1

2021 Kit 1						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 5 bulbs)	0.06775	66.8	0.06225	61.4	0.05652	55.7
CEE Tier 1, Omnidirectional 5.5W LED Bulb (total for 3 bulbs)	0.02484	24.5	0.02283	22.5	0.02073	20.4
CEE Tier 1, Omnidirectional 11W LED Bulb (total for 2 bulbs)	0.03312	32.6	0.03043	30.0	0.02763	27.2
2021 Kit 1 Total	0.12571	123.9	0.11551	113.8	0.10488	103.4

2021 Kit 2						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 5 bulbs)	0.06775	66.8	0.06225	61.4	0.05652	55.7
CEE Tier 1, Omnidirectional 5.5W LED Bulb (total for 3 bulbs)	0.02484	24.5	0.02283	22.5	0.02073	20.4
CEE Tier 1, Omnidirectional 11W LED Bulb (total for 2 bulbs)	0.03312	32.6	0.03043	30.0	0.02763	27.2
1.5 GPM Faucet Aerator	0.00128	4.4	0.00128	4.4	0.00128	4.4
1.0 GPM Faucet Aerator	0.00560	19.2	0.00560	19.2	0.00560	19.2
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.01954	67.0	0.01954	67.0	0.01954	67.0
2021 Kit 2 Total	0.15213	214.5	0.14193	194.8	0.1313	184.3

Whole Home Efficiency Kit - VPPSA Customers						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 2 bulbs)	0.02710	26.7	0.02490	24.5	0.02261	22.3
CEE Tier 1, Omnidirectional 15W LED Bulb (total for 2 bulbs)	0.04580	45.1	0.04209	41.5	0.03822	37.7
Tier 1 Advanced Power Strip	0.00416	33.5	0.00416	33.5	0.00416	33.5
1.0 GPM Faucet Aerator	0.00560	19.2	0.00560	19.2	0.00560	19.2
LED Nightlight	0.00000	0.0	0.00000	0.0	0.00000	0.0
Whole Home Efficiency Kit Total	0.08265	124.5	0.07674	118.6	0.07058	112.6

Water Efficiency Kit - VPPSA Customers						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 4 bulbs)	0.05420	53.4	0.04980	49.1	0.04522	44.6
1.5 GPM Faucet Aerator	0.00128	4.4	0.00128	4.4	0.00128	4.4
1.0 GPM Faucet Aerator	0.00560	19.2	0.00560	19.2	0.00560	19.2
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.01954	67.0	0.01954	67.0	0.01954	67.0
Water Efficiency Kit	0.08062	143.9	0.07622	139.6	0.07163	135.1

Smart Connected Lighting Kit - VPPSA Customers						
Product	2021		2022		2023	
	ΔkW	ΔkWh	ΔkW	ΔkWh	ΔkW	ΔkWh
CEE Tier 1, Omnidirectional 9W LED Bulb (total for 2 bulbs)	0.02710	26.7	0.02490	24.5	0.02261	22.3

WiFi Controlled Smart Outlet	0.00000	0.0	0.00000	0.0	0.00000	0.0
Smart Motion Occupancy Sensors	0.00000	0.0	0.00000	0.0	0.00000	0.0
Smart Connected Lighting Kit Total	0.02710	26.7	0.02490	24.5	0.02261	22.3

ΔkWh_{LED}	$= SaveElec_{LED} \times ISR_{LED} \times Num_{LED}$
ΔkWh_{APS}	$= SaveElec_{APS} \times ISR_{APS}$
$\Delta kWh_{Aerator}$	$= SaveElec_{Aerator} \times ISR_{Aerator} \times Num_{Aerator} \times \%Electric\_DHW$
$\Delta kWh_{Showerhead}$	$= (SaveElec_{Showerhead} + SaveElec_{Shower\ Valve}) \times ISR_{Showerhead} \times \%Electric\_DHW$
$\Delta kWh_{Pipe\ Wrap}$	$= SaveElec_{Pipe\ Wrap} \times ISR_{Pipe\ Wrap} \times \%Electric\_DHW$

Symbol Table

Fossil Fuel Savings

Fossil Fuel Savings

Whole Home Kit 1				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
1.0 GPM Faucet Aerator	0.084	0.039	0.100	0.223
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.299	0.138	0.356	0.793
Whole Home Kit 1 Total				**1.015**

Audit Kit 1				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
Foam Insulation	0.000	0.000	0.000	0.000
Pipe Wrap Insulation (3/4")	0.024	0.032	0.033	0.089
Weatherstripping	0.000	0.000	0.000	0.000
Acrylic Caulk	0.000	0.000	0.000	0.000
Spray Foam Insulation	0.000	0.000	0.000	0.000
1.0 GPM Faucet Aerator	0.084	0.039	0.100	0.223
Audit Kit 1 Total				**0.312**

Audit Kit 2				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
1.5 GPM Faucet Aerator	0.020	0.009	0.023	0.052
1.0 GPM Faucet Aerator	0.084	0.039	0.100	0.223
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.299	0.138	0.356	0.793
Audit Kit 2 Total				**1.067**

2021 Kit 2				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
1.5 GPM Faucet Aerator	0.020	0.009	0.023	0.052
1.0 GPM Faucet Aerator	0.084	0.039	0.100	0.1223
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.299	0.138	0.356	0.793
2021 Kit 2 Total				**1.067**

Whole Home Efficiency Kit - VPPSA Customers				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
1.0 GPM Faucet Aerator	0.084	0.039	0.100	0.223
Whole Home Efficiency Kit 2 Total				**0.223**

Water Efficiency Kit - VPPSA Customers				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
1.5 GPM Faucet Aerator	0.020	0.009	0.023	0.052
1.0 GPM Faucet Aerator	0.084	0.039	0.100	0.223
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	0.299	0.138	0.356	0.793
Water Efficieny Kit 2 Total				1.067

$\Delta MMBtu_{Aerator}$	$= SaveFuel_{Aerator} \times ISR_{Aerator} \times Num_{Aerator} \times \%Fuel\_DHW$
$\Delta MMBtu_{Showerhead}$	$= (SaveFuel_{Showerhead} + SaveFuel_{Shower\ Valve}) \times ISR_{Showerhead} \times \%Fuel\_DHW$
$\Delta MMBtu_{Pipe\ Wrap}$	$= SaveFuel_{Pipe\ Wrap} \times ISR_{Pipe\ Wrap} \times \%Fuel\_DHW$

Symbol Table

Water Savings

Water Savings

Whole Home Kit 1

Product	ΔCCF
1.0 GPM Faucet Aerator	1.14
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	2.93
Whole Home Kit 1 Total	**4.07**

Audit Kit 1	
Product	ΔCCF
1.0 GPM Faucet Aerator	1.14
Audit Kit 1 Total	**1.14**

Audit Kit 2	
Product	ΔCCF
1.5 GPM Faucet Aerator	0.26
1.0 GPM Faucet Aerator	1.14
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	2.93
Audit Kit 2 Total	**4.34**

2021 Kit 2	
Product	ΔCCF
1.5 GPM Faucet Aerator	0.26
1.0 GPM Faucet Aerator	0.57
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	2.93
2021 Kit 2 Total	3.77

Whole Home Efficiency Kit - VPPSA Customers	
Product	ΔCCF
1.0 GPM Faucet Aerator	1.14
Whole Home Efficiency Kit Total	**1.14**

Water Efficiency Kit - VPPSA Customers	
Product	ΔCCF
1.5 GPM Faucet Aerator	0.26
1.0 GPM Faucet Aerator	1.14
Low-Flow Showerhead w/ Thermostatically-Initiated Shower Restriction Valve	2.93
Water Efficiency Kit Total	**4.34**

$\Delta CCF_{Aerator} = SaveWater_{Aerator} \times ISR_{Aerator} \times Num_{Aerator}$

$\Delta CCF_{Showerhead} = (SaveWater_{Showerhead} + SaveWater_{Shower\ Valve}) \times ISR_{Showerhead}$

Where:

%Electric_DHW = Proportion of water heating supplied by electricity
= 25%[7]

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane[7]

Fuel Oil	Natural Gas	Propane
26%	12%	31%

$\Delta CCF_{Aerator}$ = Gross customer annual water savings for low-flow faucet aerators (see table "Water Savings")

$\Delta CCF_{Showerhead}$ = Gross customer annual water savings for low-flow showerheads (see table "Water Savings")

$\Delta kW_{Aerator}$ = Gross customer annual kW savings for low-flow faucet aerators (see table "Electric Energy and Demand Savings")

ΔkW_{APS} = Gross customer annual kW savings for Tier 1 advanced power strips (see table "Electric Energy and Demand Savings")

ΔkW_{LED} = Gross customer annual kW savings for CEE Tier 1 omnidirectional LED bulbs (see table "Electric Energy and Demand Savings")

$\Delta kW_{Pipe\ Wrap}$ = Gross customer annual kW savings for pipe wrap insulation (see table "Electric Energy and Demand Savings")

$\Delta kW_{Showerhead}$ = Gross customer annual kW savings for low-flow showerheads (see table "Electric Energy and Demand Savings")

$\Delta kWh_{Aerator}$ = Gross customer annual kWh savings for low-flow faucet aerators (see table "Electric Energy and Demand Savings")

ΔkWh_{APS} = Gross customer annual kWh savings for Tier 1 advanced power strips (see table "Electric Energy and Demand Savings")

ΔkWh_{LED} = Gross customer annual kWh savings for CEE Tier 1 omnidirectional LED bulbs (see table "Electric Energy and Demand Savings")

$\Delta kWh_{Pipe\ Wrap}$ = Gross customer annual kWh savings for pipe wrap insulation (see table "Electric Energy and Demand Savings")

$\Delta kWh_{Showerhead}$ = Gross customer annual kWh savings for low-flow showerheads (see table "Electric Energy and Demand Savings")

$\Delta MMBtu_{Aerator}$ = Gross customer annual MMBtu savings for low-flow faucet aerators (see table "Fossil Fuel Savings")

$\Delta MMBtu_{Pipe\ Wrap}$ = Gross customer annual MMBtu savings for pipe wrap insulation (see table "Fossil Fuel Savings")

$\Delta MMBtu_{Showerhead}$ = Gross customer annual MMBtu savings for low-flow showerheads (see table "Fossil Fuel Savings")

8,760 = Number of hours per year

$HOURS_{DHW\_Conserve}$ = Annual full load hours for DHW conservation measures
= 3,427.1 hours[3]

$HOURS_{APS}$ = Average advanced power strip hours of use per year in efficient (controlled off) mode
= 8,048 hours[4]

$ISR_{Aerator}$	=	In service rate or the percentage of units rebated that actually get used, for faucet aerators = 0.57[8]
ISR_{APS}	=	In service rate or the percentage of units rebated that actually get used, for Tier 1 advanced power strips = 0.63[9]
ISR_{LED}	=	0.90[5]
$ISR_{Pipe Wrap}$	=	0.45[10]
$ISR_{Showerhead}$	=	In service rate or the percentage of units rebated that actually get used, for showerheads = 0.56[11]
$Num_{Aerator}$	=	Number of faucet aerators included in one Home Energy Kit = 2 of the 1.0 GPM faucet aerators in Whole Home Kit 1, Audit Kit 1, and Audit Kit 2 = 1 of the 1.0 GPM fuacet aerators in 2021 Kit 2 = 1 of the 1.5 GPM faucet aerators
Num_{LED}	=	Number of LED bulbs included in one Home Energy Kit

Lamp Option	Whole Home Kit 1	Whole Home Kit 2	Audit Kit 1	Audit Kit 2	2021 Kit 1	2021 Kit 2
CEE Tier 1, Omnidirectional 5.5W LED Bulb	0	0	0	0	3	3
CEE Tier 1, Omnidirectional 9W LED Bulb	2	3	4	4	5	5
CEE Tier 1, Omnidirectional 11W LED Bulb	0	0	0	0	2	2
CEE Tier 1, Omnidirectional 15W LED Bulb	2	3	0	0	0	0
CEE Tier 1, Directional 9W LED Bulb	0	2	0	0	0	0

$SaveDemand_{LED}$ = Annual electric demand savings (kW) for a CEE Tier 1 omnidirectional LED bulb[6]

Lamp Option	Demand savings (kW) for year 2021	Demand savings (kW) for year 2022	Demand savings (kW) for year 2023
CEE Tier 1, Omnidirectional 5.5W LED Bulb	0.00828	0.00761	0.00691
CEE Tier 1, Omnidirectional 9W LED Bulb	0.01355	0.01245	0.01130
CEE Tier 1, Omnidirectional 11W LED Bulb	0.01656	0.01522	0.01382
CEE Tier 1, Omnidirectional 15W LED Bulb	0.02290	0.02104	0.01911
CEE Tier 1, Directional 9W LED Bulb	0.00689	0.00646	0.00602

$SaveElec_{Aerator}$	=	Annual electric energy savings (kWh) for a low-flow faucet aerator [12] = 67.3 kWh for 1.0 GPM faucet aerator = 30.8 kWh for 1.5 GPM faucet aerator
$SaveElec_{APS}$	=	Annual electric energy savings (kWh) for a Tier 1 advanced power strip = 53.1 kWh[13]
$SaveElec_{LED}$	=	Annual electric energy savings (kWh) for a CEE Tier 1 omnidirectional LED bulb[6]

Lamp Option	Energy savings (kWh) for year 2021	Energy savings (kWh) for year 2022	Energy savings (kWh) for year 2023
CEE Tier 1, Omnidirectional 5.5W LED Bulb	8.2	7.5	6.8
CEE Tier 1, Omnidirectional 9W LED Bulb	13.4	12.3	11.1
CEE Tier 1, Omnidirectional 11W LED Bulb	16.3	15.0	13.6
CEE Tier 1, Omnidirectional 15W LED Bulb	22.6	20.7	18.8
CEE Tier 1, Directional 9W LED Bulb	6.8	6.4	5.9

$SaveElec_{Pipe Wrap}$	=	Annual electric energy savings (kWh) for pipe wrap insulation = 63.4[14]
$SaveElec_{Shower Valve}$	=	Annual electric energy savings (kWh) for a shower restriction valve = 105.2 kWh[15]
$SaveElec_{Showerhead}$	=	Annual electric energy savings (kWh) for a low-flow showerhead = 373.1 kWh[16]
$SaveFuel_{Aerator}$	=	Annual fossil fuel savings (MMBtu) for a low-flow faucet aerator[12] = 0.288 MMBtu for 1.0 GPM faucet aerator = 0.132 MMBtu for 1.5 GPM faucet aerator
$SaveFuel_{Pipe Wrap}$	=	Annual fossil fuel savings (MMBtu) for pipe wrap insulation = 0.272 MMBtu[14]
$SaveFuel_{Shower Valve}$	=	Annual fossil fuel savings (MMBtu) for a shower restriction valve = 0.451 MMBtu[15]
$SaveFuel_{Showerhead}$	=	Annual fossil fuel savings (MMBtu) for a low-flow showerhead = 1.600 MMBtu[16]
$SaveWater_{Showerhead}$	=	Annual water savings (CCF) for a low-flow showerhead = 4.09 CCF[16]
$SaveWater_{Aerator}$	=	Annual water savings (CCF) for a low-flow faucet aerator[12] = 1.00 CCF for 1.0 GPM faucet aerator = 0.46 CCF for 1.5 GPM faucet aerator
$SaveWater_{Shower Valve}$	=	Annual water savings (CCF) for a shower restriction valve = 1.15 CCF[15]

Load Shapes

For aerators, showerheads, and shower valves:

For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

Loadshapes #8 is based on Itron 8760 hourly load data.

For pipe wrap insulation:

7a Residential DHW insulation

For controlled power strips: see file Loadshape_smart_revB.xls.

For LED bulbs:

Residential: Loadshape #1: Residential Indoor Lighting

1a Residential Indoor Lighting
7a Residential DHW insulation
8a Residential DHW conserve
96a Standby Losses - Entertainment Center

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9%	35.0%	13.0%	15.1%	29.8%	8.2%
7	Residential DHW insulation	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%
8	Residential DHW conserve	Active	48.7%	29.1%	14.3%	7.9%	40.1%	20.3%
96	Standby Losses - Entertainment Center	Active	32.0%	35.0%	16.0%	17.0%	72.5%	90.0%

Net Savings Factors

Measures

ZZZEEKIT	Home Energy Efficiency Kit

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6032LIEP [6032EPEP]	Efficient Products - Low Income

Lifetimes

See the table below for the measure lifetime for each product included in a Home Energy Kit.

Product	Lifetime (years)
CEE Tier 1 Omnidirectional LED Bulbs	15[17]
Tier 1 Advanced Power Strips	5[18]
Low-Flow Faucet Aerators	10[19]
Low-Flow Showerheads w/ Thermostatically-Initiated Shower Restriction Valves	10[19]
Pipe Wrap Insulation	12[20]

Measure Cost

The measure cost is the actual cost of the kit incurred by the program, as detailed in the following table:

Incremental Cost	
Whole Home Kit 1	$65.00
Whole Home Kit 2	$52.50
Audit Kit 1	$50.50
Audit Kit 2	$49.00
2021 Kit 1	$22.40
2021 Kit 2	$34.15
Whole Home Efficiency Kit - VPPSA Customers	$39.50
Water Efficiency Kit - VPPSA Customers	$43.50
Smart Connected Lighting Kit - VPPSA Customers	$57.00

O&M Cost Adjustments

To account for the shift in baseline due to replacement lamps, the levelized baseline replacement cost over the lifetime of the LED lamps is calculated based on the following assumptions.[21]

Lamp Type	Omnidirectional	Directional	Assumed Lifetime (hours)
LED	$5.00	$10.00	
CFL	$2.50	$4.50	10,000
Halogen	$1.25	$3.50	1,000
Incandescent	$0.50	$3.50	1,000

The calculation results in the following equivalent annual baseline replacement cost.

Measure	Annual baseline O&M assumption for bulbs installed in		
	2021	2022	2023
CEE Tier 1, Omnidirectional 9W LED Bulb (60W equivalent)	$0.39	$0.37	$0.35
CEE Tier 1, Omnidirectional 15W LED Bulb (100W equivalent)	$0.39	$0.37	$0.35
CEE Tier 1, Directional 9W LED Bulb (65W equivalent)	$1.08	$1.02	$0.96
Ominidirectional 5.5W LED Bulb (40W equivalent)	$0.39	$0.37	$0.35
Ominidirectional 11W LED Bulb (75W equivalent)	$0.39	$0.37	$0.35

Reference Tables

Measure	Item Code
Whole Home Kit 1	RES-EEKIT-WHK1
Whole Home Kit 2	RES-EEKIT-WHK2
Audit Kit 1	RES-EEKIT-AK1
Audit Kit 2	RES-EEKIT-AK2
2021 Kit 1	RES-EEKIT-211
2021 Kit 2	RES-EEKIT-212
Whole Home Efficiency Kit	RES-EEKIT-VPPSA1
Water Efficiency Kit	RES-EEKIT-VPPSA2
Smart Connected Lighting Kit	RES-EEKIT-VPPSA3

Footnotes

[1] Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[2] For additional details on the baseline adjustment calculation see reference file, "EVT_Home Energy Kit_Analysis_Feb 2021.xlsx". And for the derivation of the market forecast and accompanying bulb wattage estimates, see reference file, "2021-2023 EVT Lamp Analysis.xlsx".

[3] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[4] Derived from CalPlug Tier 2 APS Evaluation Study Retrieved from: http://embertec.com/assets/pdf/CalPlug_Tier2_APS_Evaluation.pdf.

Advanced power strips are assumed to be plugged in at all times. Annual hours when the equipment is turned off are 7,340. The equipment is estimated to be in standby mode 1.94 hours/day or 708 hours/year. Savings are achieved during periods when equipment is off or in standby mode. Thus, the hours of operation used to determine demand savings are 7,340 + 708 = 8,048. No savings are achieved during the remaining 712 hours per year when equipment is in use.

[5] Lifetime ISR for LED bulbs based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a

1st Year ISR of 70% (1st year ISR value for both CFL and LED bulbs in efficiency kits is 59% in the Illinois Technical Reference Manual for Energy Efficiency, Version 6.0 ("Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B."). Efficiency Vermont assumes the ISR for free LED bulbs is higher than for free CFL bulbs.) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 90%. See file EVT_Home Energy Kit_Analysis_Feb 2021.xlsx for calculaton details.

[6] Annual kW and kWh values for LED bulbs assume an LED bulb wattage of 5.5W, 9W, 11W, and 15W for the omnidirectional products and 9W for the directional product, which is the actual wattage of LED lamps provided in Home Energy Kits. Baseline wattage values are based on a 40W-equivalent bulb, 60W-equivalent bulb, 75W-equivalent bulb, 100W-equivalent bulb, and a 65W-equivalent bulb, respectively. For additional details on the energy and demand savings calculation see reference file, "EVT_Home Energy Kit_Analysis_Jun 2021.xlsx". And for the derivation of the market forecast and accompanying bulb wattage estimates, see reference file, "2021-2023 EVT Lamp Analysis.xlsx".

[7] DHW fuel percentages sourced from "Vermont Single-Family Existing Homes On-Site Report", NMR, July 2018; Table 59: Water Heating System Fuel (pg. 52)

[8] Average of kits aerator in service rate (average of 61.5%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits aerator in service rate for single family homes (52%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[9] Advanced power strip ISR is average of ISRs from Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five," November 13, 2014, p. 147.

[10] In the absence of evaluation studies supporting an ISR for free pipe wrap insulation, EVT leveraged the ISR assumptions of a stand-alone free shower restriction valve, which was used in the previous iteration of this measure. The shower restriction valve was assigned an ISR of 45% under the logic that customers would be less familiar with these products. Using the same product familiarity principal established with shower restriction valves, EVT assigned a similar 45% ISR for pipe wrap insulation, assuming customers would react in a similar manner.

[11] Average of showerhead in service rate for kits including one showerhead (65%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits showerhead in service rate for single family homes (47%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[12] Annual kWh, MMBtu, and CCF values for faucet aerators are Direct Install values for 1.0 and 1.5 gpm aerators from the "Low Flow Faucet Aerator" measure (effective 01/01/2017) under the Existing Homes program within the EVT TRM.

[13] Annual kWh savings value for Tier 1 advanced power strips is from the "Controlled Power Strip" measure (effective 01/01/2018) under the Efficient Products program within the EVT TRM. Values for entertainment centers (75.1 kWh) and home offices (31 kWh) were averaged.

[14] Annual kWh and MMBtu values for pipe wrap insulation for 3/4" pipes from the "Pipe Wrap" measure (effective 01/01/2017) under the Existing Homes program within the EVT TRM.

[15] Annual kWh, MMBtu, and CCF values for shower restriction valves are from the "Thermostatically Initiated Shower Restriction Valve" measure (effective 01/01/2018) under the Efficient Products program within the EVT TRM.

[16] Annual kWh, MMBtu, and CCF values for low-flow showerheads are from the "Low Flow Showerhead" measure (effective 01/01/2017) under the Existing Homes program within the EVT TRM.

[17] The lifetime for LED bulbs is the actual rated life of the product provided in kits (25,000 hours) divided by annual hours of use (986 hours). All lighting lifetimes are capped at 15 years (although their rated life/hours is higher).

[18] 10-year estimate: Lockheed Martin, Inc., Energy Solutions, Advanced Power Strip Research Report Final Report, Prepared for the New York State Energy Research and Development Authority (NYSERDA), 2011. As persistence has not been studied for this measure, 5 years is being used as a conservative estimate.

[19] Both low flow showerheads and thermostatically-initiated shower restriction valves have a measure life of 10 years. As the offered product is a low flow showerhead with an integrated thermostatic restriction valve, the 10 year measure life was deemed appropriate. The low flow showehead measure is sourced from California DEER; see file DEER2014-EUL-table-update_2014-02-05.xlsx. And the thermostatically-initiated shower restriction valve measure life is sourced from California DEER Ex-Ante Database.

[20] Measure lifetime from California DEER. Average of values for electric DHW (13 years) and gas DHW (11 years); see file DEER2014-EUL-table-update_2014-02-05.xlsx.

[21] For additional details on O&M cost adjustments see reference file, "EVT_Home Energy Kit_Analysis_Jun 2021.xlsx".

ENERGY STAR Ceiling Fan

Measure Number: VII-C-15 a
Portfolio: EVT TRM Portfolio 2018-12
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Multiple End Uses

Update Summary

New measure

Referenced Documents

- EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017
- ENERGY STAR Ceiling Fans Product Specification Version 4
- U.S. DOE Code of Federal Register (CFR)_Federal Baseline_2017
- ENERGY STAR Light Fixture_Ceiling Fan Calculator
- EVT Residential Ceiling Fan Analysis

Description

This measure is the installation of a residential ceiling fan with and without lighting fixtures that meets the minimum ENERGY STAR efficiency specifications.

Baseline Efficiencies

The baseline equipment is assumed to be a residential ceiling fan meeting federal equipment standards[1] with EISA qualified incandescent or halogen light bulbs.

Efficient Equipment

The efficient equipment is a residential ceiling fan meeting the minimum ENERGY STAR specifications.[2]

Algorithms

Electric Demand Savings

ΔkW	$= \Delta kW_{Fan} + \Delta kW_{Light}$
ΔkW_{Fan}	$= (\text{Watts High}_{Base} - \text{Watts High}_{EE}) / 1000$
ΔkW_{Light}	$= ((\text{Watts}_{Base} - \text{Watts}_{EE}) / 1000) \times WHF_d$

Symbol Table

Electric Energy Savings

ΔkWh	$= \Delta kWh_{Fan} + \Delta kWh_{Light}$
ΔkWh_{Fan}	$= (\text{Days} \times \text{Hours} \times ((\%\ \text{Low}_{Base} \times \text{Watts Low}_{Base}) + (\%\ \text{Med}_{Base} \times \text{Watts Med}_{Base}) + (\%\ \text{High}_{Base} \times \text{Watts High}_{Base}))/1000) - (\text{Days} \times \text{Hours} \times ((\%\ \text{Low}_{EE} \times \text{Watts Low}_{EE}) + (\%\ \text{Med}_{EE} \times \text{Watts Med}_{EE}) + (\%\ \text{High}_{EE} \times \text{Watts High}_{EE}))/1000)$
ΔkWh_{Light}	$= ((\text{Watts}_{Base} - \text{Watts}_{EE}) / 1000) \times \text{Hours} \times \text{Days} \times WHF_e$

Symbol Table

Fossil Fuel Savings

Where:

$\%\ \text{High}_{Base}$	=	Percent of time baseline equipment is run on high speed 20%[5]
$\%\ \text{High}_{EE}$	=	Percent of time efficient equipment is run on high speed 20%[5]
$\%\ \text{Low}_{Base}$	=	Percent of time baseline equipment is run on low speed 40%[5]
$\%\ \text{Low}_{EE}$	=	Percent of time efficient equipment is run on low speed 40%[5]
$\%\ \text{Med}_{Base}$	=	Percent of time baseline equipment is run on medium speed 40%[5]
$\%\ \text{Med}_{EE}$	=	Percent of time efficient equipment is run on medium speed 40%[5]
ΔkW_{Fan}	=	Gross customer connected load kW savings associated with the ceiling fan
ΔkW_{Light}	=	Gross customer connected load kW savings associated with the lights
ΔkW	=	Gross customer connected load kW savings for the measure
ΔkWh_{Fan}	=	Gross customer annual kWh savings associated with the ceiling fan
ΔkWh_{Light}	=	Gross customer annual kWh savings associated with the lights
ΔkWh	=	Gross customer annual kWh savings for the measure
Days	=	Number of days per year equipment is in use 365 days
Hours	=	Average number of hours per day equipment is in use 3 hours/day[5]
Watts High_{Base}	=	Baseline fan wattage at high speed 67 watts[6]
Watts High_{EE}	=	Efficient fan wattage at high speed 31 watts[7]
Watts Low_{Base}	=	Baseline fan wattage at low speed 15 watts[6]
Watts Low_{EE}	=	Efficient fan wattage at low speed 3 watts[7]

Watts Med_{Base}	=	Baseline fan wattage at medium speed 34 watts[6]
Watts Med_{EE}	=	Efficient fan wattage at medium speed 13 watts[7]
$Watts_{Base}$	=	Total input wattage of the baseline lamps. Please see the reference table section for more detail, as the baseline lamp wattage varies depending on the replacement scenario.[3]
$Watts_{EE}$	=	Total input wattage of the efficient lamps 16.4 watts[8]
WHF_d	=	Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings. The value for residential lighting is assumed to be 1.0.
WHF_e	=	Waste heat factor for energy to account for cooling savings from efficient lighting. The value for residential lighting is assumed to be 1.0.

Baseline Wattage

Replacement Scenario	2019-2020 $Watts_{Base}$	2021 $Watts_{Base}$
Conventional[3]	73.3	29.4
Residential New Construction (RNC)[4]	37.7	26.7

Deemed Energy and Demand Savings

Measure Description	Item Code	2019 - 2020 (Annual Savings)		2021 (Annual Savings)	
		ΔkW	ΔkWh	ΔkW	ΔkWh
Ceiling Fan Only	CEILFAN	0.0360	22	0.0360	22
Lights Only		0.0569	62	0.0130	14
RNC Lights Only		0.0213	23	0.0103	11
Ceiling Fan w/ Light Kit	CEILFANL	0.0929	84	0.0490	36
RNC Ceiling Fan w/ Light Kit	CEILFANLRNC	0.0573	45	0.0463	33

Load Shapes

1a Residential Indoor Lighting
10a Residential Ventilation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9%	35.0%	13.0%	15.1%	29.8%	8.2%
10	Residential Ventilation	Active	31.7%	34.9%	15.9%	17.5%	32.2%	32.2%

Net Savings Factors

Measures

VNTCLFAN	Ceiling fan

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6038VESH [is base track]	RNC VESH
6041LINC [6038VESH]	Low Income Single Family New Construction

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	VNTCLFAN	1.00	1.00
RNC VESH	6038VESH	VNTCLFAN	0.95	1.10

Lifetimes

Measure life is estimated to be 15 years[9]

Measure Cost

The incremental cost for this measure is:

Measure Description	Item Code	Incremental Cost[10]
Ceiling Fan Only	CEILFAN	$33.45
Ceiling Fan w/ Light Kit	CEILFANL	$46.00
RNC Ceiling Fan w/ Light Kit	CEILFANLRNC	$45.19

O&M Cost Adjustments

Lamp Type	Annual baseline O&M assumptions for bulbs installed		
	2019	2020	2021
Ceiling Fan w/ Light Kit	$0.43	$0.32	$0.21
RNC Ceiling Fan w/ Light Kit	$0.26	$0.23	$0.21

Footnotes

[1] U.S. DOE Code of Federal Register, Rules and Regulations Docket Number EERE-2012-BT-STD-0045, Energy Conservation Program: Energy Conservation Standards for Ceiling Fans (10 CFR Part 430), January 19, 2017

[2] ENERGY STAR Program Requirements, Product Specification for Residential Ceiling Fans and Ceiling Fan Light Kits, Version 4.0, effective June 15, 2018

[3] The baseline lamp wattages are assumed to be EISA impacted incandescent or halogen light bulbs. The regulations stipulate that by January 1, 2020, all lamps must meet the efficiency criteria of at least 45 lumens per watt. Due to the expected delay in clearing retail inventory and to account for the operating life of an incandescent and halogen lamp, the shift is expected not to occur in 2021. As a result, there are two baseline wattages listed for this measure, 73.3 watts for years 2019 and 2020 and 29.4 watts for 2021 and beyond. The wattages are based on CFL and LED equivalent baseline wattages as sourced from the "EVT ENERGY STAR LED Lamp Analysis" and scaled then weighted based on ENERGY STAR available products on the Qualified Products List, as pulled on 10/11/2018.

[4] The RNC baseline lamp wattage uses similar assumptions as the market opportunity baseline with EISA impacted incandescent or halogen light bulbs. Additionally, Vermont residential code stipulating 75% of permanently installed fixtures meet high efficacy requirements was factored into the baseline lamps and weighted accordingly.

[5] The percent of time the ceiling fan is operated at the varying speeds (low/medium/high) and the run hours per day is sourced from the ENERGY STAR Calculator.

[6] The baseline wattages at the varying speeds (low/medium/high) is sourced from the ENERGY STAR Calculator.

[7] The efficient wattages at the low and high speed settings are sourced from the average of available products on the ENERGY STAR Qualified Products List (QPL), as pulled on 10/11/2018. The efficient wattage at the medium speed is interpolated based on the varying speed wattages from the ENERGY STAR version 3.0, as sourced from the ENERGY STAR Calculator. For more information on the QPL data set, please see 'EVT Residential Ceiling Fan Analysis.xlsx'

[8] The efficient wattage is based on the average ceiling fan light kit wattage, as sourced from the ENERGY STAR QPL, as pulled on 10/11/2018. For reference, the QPL had 6 ceiling fan light kits that had CFL lamps, averaging 2.2 bulbs per kit, and 43 ceiling fan light kits that had LED lamps, averaging 1.2 bulbs per kit.

[9] Measure life is sourced from the ENERGY STAR Calculator and accounts for a blended liftime of the applicable ceiling fan light kit lamp types

[10] The incremental cost for the ceiling fan with light kit is sourced from the ENERGY STAR Calculator. The incremental cost for just the ceiling fan was back-tracked by subtracting the weighted average incremental cost of the light kits by leveraging lamp cost information from the "EVT ENERGY STAR LED Lamp Analysis".

Comprehensive Shell Measure Savings

Measure Number: VI-L-1 b
Portfolio: 81a
Status: Active
Effective Date: 2014/1/1
End Date: [None]
Program: Residential New Construction
End Use: Multiple End Uses

Referenced Documents

1. VT UDRH_Baseline2011_Input Data_MEDIAN-FINAL_121613.xlsx
2. VT UDRH_Baseline2011_REMv14.3_MEDIAN-FINAL_121613.udr
3. RNC UDRH 2013 Update_Memo to PSD_FINAL bm.docx

- VESH Requirements

Description

This measure characterization documents the methodology and key assumptions for comprehensive residential new construction savings due to thermal shell and mechanical equipment improvements. This characterization includes savings for heating, cooling and hot water end uses[1].

Estimated Measure Impacts

Algorithms

Demand Savings

$$\text{Demand Savings} = \text{Demand}_{AsBuilt} - \text{Demand}_{UDRH}$$

Symbol Table

Energy Savings

$$\text{Energy Savings} = \text{Energy}_{AsBuilt} - \text{Energy}_{UDRH}$$

Where:

$\text{Demand}_{AsBuilt}$	=	REM/Rate modeled demand (kW) of the AsBuilt home
Demand_{UDRH}	=	REM/Rate modeled demand (kW) of the UDRH home
$\text{Energy}_{AsBuilt}$	=	REM/Rate modeled consumption (kWh and MMBtu) of the AsBuilt home
Energy_{UDRH}	=	REM/Rate modeled consumption (kWh and MMBtu) of the UDRH home

Energy and demand savings will be calculated using the User Defined Reference Home (UDRH) feature in REM/Rate™. All Residential New Construction Projects will be modeled in REM/Rate™ to estimate annual energy consumption and demand for heating, cooling and hot water. Each project will be modeled a second time to a baseline[2] specification. The difference in modeled energy consumption and demand between the AsBuilt project and UDRH baseline models will be the savings for that project.

Baseline Efficiencies

The following table provides an overview of the UDRH baseline specification[3]. The efficiencies listed below for the Energy Code Plus and ENERGY STAR program tiers are a mixture of prescriptive program guidelines and mandatory prescriptive requirements. Mandatory requirements are noted with an asterisk. Each program home will be unique and may fall above or below the efficiency guidelines listed below. All homes must meet a minimum performance (HERS) target[4].

		Baseline Efficiency	Above-Baseline Efficiency	
		UDRH	***Energy Code Plus***	***ENERGY STAR***
Heating	Boiler, gas/prop	94.1 AFUE	85 AFUE*	
	Boiler, oil/kero	86.9AFUE		
	Furnace, gas/prop	87.0 AFUE	95 AFUE*	
	Furnace, oil/kero	83.0 AFUE	85 AFUE*	
Cooling	CAC	13 SEER	14.5 SEER*	
Heat Pump	ASHP	7.7 HSPF / 13 SEER	ENERGY STAR qualified*[5]	
	GSHP	3.1 COP / 11.24 EER		
Domestic Hot Water	Tank, gas/prop	0.62 EF	0.59 EF	
	Tank, oil/kero	0.49 EF	0.51 EF	
	Instant, gas/prop	0.82 EF	0.82 EF	
	Indirect, gas/prop	0.87 EF		
	Indirect, oil/kero	0.80 EF	N/A	
Air Leakage	Infiltration	3.4 ACH50	4 ACH50*	3 ACH50*
Thermal Shell	Insulation Grade[6]	2	2	1
	Ceiling	R-38	R-49	
	Above-grade walls	R-19	R-20	
	Foundation Wall	R-10	R-15	
	Slab-on-Grade	R-10	R-15	
	Frame floors	R-24	R-30	
	Windows	U - 0.34	U - 0.32*	

High Efficiency
See under Baseline Efficiency above.

Operating Hours

Load Shapes
7a Residential DHW insulation
5b Residential Space heat
11b Residential A/C

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%
11	Residential A/C	Active	6.6%	3.8%	51.1%	38.6%	0.0%	16.0%

Net Savings Factors
Measures

TSHCOMPH	Comprehensive Thermal Measure REMRate Calculated Heating
TSHCOMPC	Comprehensive Thermal Measure REMRate Calculated Cooling
HWECOMP1	Comprehensive Thermal Measure REMRate Calculated DHW

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	TSHCOMPH	0.95	1.10
RNC VESH	6038VESH	TSHCOMPC	0.95	1.10
RNC VESH	6038VESH	HWECOMP1	0.95	1.10

Persistence
The persistence factor is assumed to be one.

Lifetimes
25 years.

Analysis period is the same as the lifetime.

Measure Cost
$3,627[1188]

O&M Cost Adjustments

Fossil Fuel Description

Footnotes
[1] This comprehensive measure characterization replaces the following Residential New Construction measures: Heating Savings, Efficient Furnace Fan Motor, Central Air Conditioner, Space Cooling Savings, ES Central Air Conditioner, and Fossil Fuel Water Heater

[2] Baseline specifications are derived from the Vermont Residential New Construction Baseline Study Analysis of On-Site Audits Final Report, February 13, 2013. A new UDRH baseline will be submitted to DPS for review within three months of final updates to a new Vermont RNC baseline study.

[3] See Reference document VT UDRH_Baseline2011_Input Data_MEDIAN-FINAL_121613.xlsx for the detailed specification.

[4] Efficiency Vermont Residential New Construction Requirements and Specifications http://www.efficiencyvermont.com/docs/for_my_home/rnc/VESH_Requirements.pdf

[5] http://www.energystar.gov/index.cfm?c=products.pr_find_es_products

[6] Insulation grade refers to the quality of insulation installation. Research has shown insulation is typically installed poorly and not to manufacturer's specifications. This has a significant impact on energy performance of the insulation. Grade 1 (per manufacturer instructions) is required by ENERGY STAR Homes.

Door Heater Controls

Measure Number: CI-RFG-DHC e
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

March 2021 Update Summary:

- Updated the characterization to match new template (new measure number, added sections, item codes, etc.)
- Updated bonus factor to maintain consistency with other refrigeration measures
- Updated measure lifetime - Previous life time estimate appeared to be based on general commercial refrigeration equipment (10 years). Revised measure life time is consistent with our refrigeration case measures (add doors to open display cases) and industry estimates.
- Added an unknown cooler type option

Referenced Documents

- United States Department of Energy 10 CFR Part 431, Docket No. EERE-2010-BT-STD-0003, 2010
- Anti-Sweat Door Heater Controls NEEP ICS4 Final June 23 2015
- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Door Heater Control Study 2016 v2.xls
- SWCR001-01 Anti Sweat Heater Controls_May 2019
- EVT_Door Heat Control_Analyis_Mar 2021

Description

Another option to zero-energy doors – that is also effective on existing reach-in cooler or freezer doors – is "on-off" control of the operation of the door heaters. Because relative humidity levels differ greatly across the United States, a door heater in Vermont needs to operate for a much shorter season than a door heater in Florida. By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize energy and cost savings.

There are two strategies for this control, based on either (1) the relative humidity of the air in the store or (2) the "conductivity" of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

Program Type

Calculation Type: Retrofit

Implementation Type: Downstream

Baseline Efficiencies

The baseline condition is a cooler or freezer glass door that is continuously heated to prevent condensation.

Efficient Equipment

High efficiency is a cooler or freezer glass door with a humidity-based door-heater control.

Algorithms

Electric Demand Savings

ΔkW	$= kW_{door} \times N_{door} \times ES \times BF$

Symbol Table

Electric Energy Savings

ΔkWh	= ΔkW × 8760

Symbol Table

Fossil Fuel Savings

Where:

ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
ΔkW	=	Gross customer connected load kW savings for the measure (kW)
8760	=	Hours / Year
BF	=	Bonus factor for reduced cooling load from eliminating heat generated by the door heater from entering the cooler or freezer[1] = 1.4 for coolers = 1.8 for freezers = 1.4 for unknown
ES	=	Percent annual energy savings from off-time of heating elements = 45.1%[2]
kW_{door}	=	Connected load kW of a typical reach-in cooler or freezer door and frame with a heater[3] = 0.066 kW for coolers = 0.230 kW for freezers = 0.130 kW for unknown
N_{door}	=	Number of doors controlled by sensor

Load Shapes

For Loadshape details, see reference: EVT_Door Heater Control_Analysis_Mar 2021.xls

69b Door Heater Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
69	Door Heater Control	Active	29.0%	38.0%	15.0%	18.0%	90.9%	96.5%

Net Savings Factors

Measures

RFRDRCON	Refrigeration door heater controls

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Lifetimes

12 years[4]

Measure Cost

The cost for a refrigeration door heater control unit is $971. When evaluated on a per door basis costs are estimated at $121 per cooler door and $214 per freezer door.[5]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Reference Tables

Measure Application (Case Type)	Units	Item Code	ΔkW	ΔkWh	Incremental Cost
Cooler	per door	CEO-RFR-DHC-H / CEO-RFR-DHC-M	0.04167	365	$121
Freezer	per door	CEO-RFR-DHC-L	0.18671	1,636	$214
Unknown	per door	CEO-RFR-DHC-U	0.08208	719	$145

Footnotes

[1] Bonus factors as derived in the NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. (Page 78, Figure 54). The 1.4 unknown case type bonus factor represents a weighted average of low, medium, and high temperature refrigeration types.

[2] Difference in effective runtime of an uncontrolled heater and all control style heater controls. Anti-sweat door heater control reduced run time. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 69, Section 4.1.4, Table 37.

[3] Wattages per door derived from NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015 (pg. 57). For more detail, see reference file: EVT_Door Heater Control_Analysis_Mar 2021.xls

[4] Commercial Refrigeration Anti-Sweat Heater Controls, California Technical Forum, Workpaper SWCR001-01, May 2019

[5] Heater control unit costs were determined from the NEEP Incremental Cost Study Part 4 spreadsheet as listed for the New England region on a per controller and per door cost basis. See reference "Anti-Sweat Door Heater Controls NEEP ICS4 Final June 23 2015.xlsx", "Summary of Results" tab. The cost for the unknown case types is weighted using sample data from: NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015

Add Doors to Open Display Cases

Measure Number: CI-RFG-DOOR b
Portfolio: EVT TRM Portfolio 2020-03
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

Corrected a math error in the calculation of the cooling interactive effects. Revisions were made to the $\Delta kWh_{A/C}$ algorithm and to the deemed savings values and table.

Referenced Documents

- Lighting Efficiency Waste Heat Adjustment Methodology
- EVT Refrigeration Analysis Tool v5b
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- PG&E, "Add Doors to Open, Medium-Temperature Cases", Work Paper PGE3PREF116, April 2014
- New York Standards Approach for Estimating Energy Savings_v6_January 2019
- EVT_Add Doors_Analysis_Apr 2020

Description

Open display cases are typically found in grocery and convenience stores, and have been a preference of store owners because they allow customers a clear view and easy access to refrigerated products. This measure is retrofitting existing, open, refrigerated display cases by adding and installing doors. The baseline equipment is an open vertical or horizontal display case with no doors or covering. The efficient equipment is the installation of solid doors on the existing display case. Replacement of open display cases with new display cases with doors is not covered under this measure characterization. High, medium, and low temperature cases are eligible; however, the measure assumptions detailed in this characterization are based on medium temperature display cases, with the installation of zero energy doors, as it was deemed the most likely candidate for participation in this measure. Additionally, this measure is only applicable for sites less than 10,000 sqft in building space. Sites over this threshold and other larger grocery stores are not eligible for this measure and their participation will be conducted on a custom basis.

Energy savings are based on air infiltration reduction from the addition of doors to the open display cases. The air infiltration reductions assume a reduced heat gain and subsequent reduced load on the refrigeration compressors. Both radiant and conduction heat losses were factored into the analysis as well. Energy savings are based on a per linear foot of display case.

Interactive HVAC energy savings were also included in the measure savings analysis. The HVAC interactive effects calculation assesses the measure's impact on the heating and cooling equipment. With adding a door to an open refrigerated display case, excess cold air leaking into the conditioned space no longer has to be treated by the heating system, resulting in additive savings. Similarly, the reduction in cold air from the open refrigerated display case no longer supplements the efforts of the space cooling equipment, which results in an overall increase in its consumption.

Program Type

Retrofit

Baseline Efficiencies

The baseline condition is an open, refrigerated, display case without any covering.

Efficient Equipment

The efficient condition is retrofitting an existing open, refrigerated, display case by adding doors.

Algorithms

Electric Demand Savings

ΔkW_{Case}	$= \Delta kWh_{Case} / 8760$
$\Delta kW_{A/C}$	$= \Delta kWh_{A/C} / Hours_{Cooling}$
ΔkW	$= \Delta kW_{Case} + \Delta kW_{A/C}$

Symbol Table

Electric Energy Savings

ΔkWh_{Case}	$= ((\Delta HG \times CL) / (EER \times 1000)) \times 8760$
$\Delta kWh_{A/C}$	$= MMBtu_{HVAC\ Cool} \times CL \times (1 / SEER) \times 1000$
ΔkWh	$= \Delta kWh_{Case} + \Delta kWh_{A/C}$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu$	$= MMBtu_{HVAC\ Heat} \times CL \times (1 / AFUE)$

Symbol Table

Water Savings

N/A

Where:

ΔHG	=	Heat Gain; the decreased load or the reduced heat gain on the open refrigerated display case with the installation of a door (Btu/hr-linear foot) = 1,148 Btu/h-ft[3]
$\Delta kW_{A/C}$	=	Gross connected load kW increase associated with the space cooling equipment
ΔkW_{Case}	=	Gross connected load kW savings associated with the open refrigerated display case
ΔkW	=	Gross customer connected load kW savings
$\Delta kWh_{A/C}$	=	Gross annual kWh energy increase associated with the space cooling HVAC equipment
ΔkWh_{Case}	=	Gross annual kWh energy savings associated with the open refrigerated display case
ΔkWh	=	Gross customer annual kWh energy savings
$\Delta MMBtu$	=	Gross customer annual MMBtu fossil fuel savings
1000	=	Conversion from watts to kilowatts (W / kW)
8760	=	Annual operating hours of the refrigerated display case
AFUE	=	Annual Fuel Utilization Efficiency; HVAC heating equipment operating efficiency = 86.8%[8]

CL	=	Case Length; refrigerated case length in feet = 1[4]
EER	=	Energy Efficiency Ratio; display case compressor efficiency (Btu/hr-watt) = 11.36[5]
$Hours_{Cooling}$	=	Total combined hours the site is providing cooling = 2,420 hours[2]
$MMBtu_{HVAC\ Cool}$	=	Total cooling load increase on the HVAC equipment per linear foot of display case = -2.084 MMBtu[6]
$MMBtu_{HVAC\ Heat}$	=	Total heating load decrease on the HVAC equipment per linear foot of display case = 6.289 MMBtu[9]
SEER	=	Seasonal Energy Efficiency Ratio; HVAC equipment operating efficiency (Btu/hr-watt) = 11.7[7]

Deemed Energy and Demand Savings

Measure	Item Code	Demand Savings (ΔkW / linear foot)	Annual Energy Savings (ΔkWh / linear foot)	Fossil Fuel MMBtu Savings (ΔMMBtu / linear foot)[1]		
				Oil	Natural Gas	Propane
Adding Doors to Open Display Cases		0.1011	885.6	0	0	0
HVAC Interactive Effects		-0.0736	-178.1	1.398	2.595	2.296
Overall Measure Savings	CEO-RFR-DOOR	0.0275	707.5	1.398	2.595	2.296

Mid-Life Savings Adjustment

N/A

Load Shapes

14a Commercial Refrigeration
15c Commercial A/C

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
14	Commercial Refrigeration	Active	33.0%	32.6%	17.0%	17.4%	69.0%	77.2%
15	Commercial A/C	Active	18.0%	10.0%	46.0%	26.0%	0.0%	34.2%

Net Savings Factors

Measures

RFRDOORS	Add Doors to Open Refrigerated Cases

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl

Lifetimes

The measure life is 12 years[10]

Measure Cost

The incremental cost, which includes both material and labor, is $521.55 per linear foot.[11]

O&M Cost Adjustments

N/A

Reference Tables

N/A

Footnotes

[1] The split in fossil fuel MMBtu heating savings is sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 30, 2017. The oil and natural gas equipment distribution is sourced from page 65. However, propane equipment was not included in this breakdown, so in order to include propane equipment distribution, leveraged data from the overall heating system fuel type from page 63 and shifted the % breakdown of propanes in percentage points to match the oil and natural gas furnace breakdown. For more information, please see "EVT_Add Doors_Analysis_Apr 2020.xlsx"

[2] The total combined hours in which the site is providing cooling is based on an outdoor air temperature bin analysis, where the site is conditioning cold air at outdoor temperatures of 60ºF and above. For more information on the derivation of these hours, please see 'HVAC IE' tab in the "EVT_Add Doors_Analysis_Apr 2020.xlsx"

[3] The change in heat gain is sourced as the typical value for a medium temperature display case adding doors from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases - PGE3PREF116", April 2014. The workpaper assumes a net reduction in heat gain with the installation of doors on open refrigerated display cases. The primary benefits account for the decrease in excess heat entering the display case from air infiltration. Radiation and conduction heat gains were also included in the derivation of this value. Additionally, the net heat gain has built in assumptions on how often the refrigerated case doors will be used and the display case accessed by customers and site associates, reducing some of the air infiltration benefits of the new door.

[4] Energy savings are based on a unit basis of "per linear foot" of open display case. As a result, for practical purposes involving the energy savings algorithm, the deemed value for the case length is 1 foot.

[5] The EER is sourced as the average compressor efficiency for medium temperature cases (11.36 EER; case temperature 10°F to 40°F). This value was calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and a saturated suction temperatures (SST) of 20°F for medium temperature applications. These EER values were developed in "EVT Refrigeration Analysis Tool v5b" utilizing data from Emerson Climate Technology software; last updated November 2013. It was assumed that the typical display case is a medium temperature application.

[6] The MMBtu increase on the HVAC cooling equipment is based on an outdoor air temperature bin analysis, the total hours of operation of the cooling system, and the building's overall loss of additional cooling as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain amount of conditioned air has to be treated to replace the air previously cooled by the display case. Furthermore, the analysis assumes an increased load on the cooling system, at outdoor temperatures above 60ºF. A 25% disabling factor was also applied to account for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment. For more information on the analysis used to derive the load increase on the HVAC cooling equipment per linear foot of display case, please see the 'HVAC IE' tab in the "EVT_Add Doors_Analysis_Apr 2020.xlsx"

[7] The SEER value is based on the average commercial cooling efficiency for existing buildings and is sourced from "2016 VT Business Sector Market Characterization and Assessment Study", April 30 2017 (Table 16: Cooling Efficiency of Single-Zone Unitary HVAC Systems <5.5 tons)

[8] Average AFUE of the HVAC heating equipment is based on the weighted average of existing commercial heating systems, as sourced from the "2016 VT Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). For more information on its derivation, please see 'Heating AFUE' tab in the "EVT_Add Doors_Analysis_Apr 2020.xlsx"

[9] The MMBtu decrease on the HVAC heating equipment is based on an outdoor air temperature bin analysis, the total hours of operation in which the site is providing heat, and the building's overall reduced heating load as a result of the installation of the doors on the open refrigerated display case. The analysis assumes a certain reduction of conditioned air that had to be treated to make up for the air previously cooled by the display case. The reduced heat gain on the refrigerated display case equals the reduced heat loss by the site and a heating load that no longer has to be provided by

the HVAC system. Furthermore, the analysis assumes a decrease load on the heating system, at outdoor temperatures below 60ºF. A 25% disabling factor was also applied to account for some of the cold air pouring out of the display case and subcooling the site's conditioned space, which will not trigger a thermostatic response from the HVAC equipment. For more information on the analysis used to derive the load decrease on the HVAC heating equipment per linear foot of display case, please see the 'HVAC IE' tab in the "EVT_Add Doors_Analysis_Apr 2020.xlsx"

[10] The measure life is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases - PGE3PREF116", April 2014.

[11] The incremental cost is sourced from the PG&E Workpaper, "Add Doors to Open Medium Temperature Cases - PGE3PREF116", April 2014

Evaporator Fan Motor Controls

Measure Number: CI-RFG-EVPMC e
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

March 2021 Update:

- Aligned characterization with new TRM template
- Updated fan motor kW to maintain consistency with other C&I evaporator measures\
- Included an unknown cooler temperature type bin
- Added a reference for the measure life

Referenced Documents

- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Oak Ridge National Laboratory, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits", 2015.
- Evaporator Fan Controls_NEEP_ICS4 Final June 23 2015.xlsx
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- Evaporator Motors Reference 2017_v4
- DEER EUL Table_2014-02-05
- EVT_Analysis_Evaporator Fan Motor Control_Mar 2021

Description

Walk-in cooler evaporator fans typically run all the time; 24 hrs/day, 365 days/yr. The continuous operation is due to the need to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. Evaporator fans controls can be added to reduce fan run time or speed depending on the call for cooling and air circulation, while maintaining circulation requirements.

Program Type

Calculation Type: Retrofit

Implementation Type: Downstream

Baseline Efficiencies

The baseline condition is a refrigeration system without an evaporator fan control.

Efficient Equipment

High efficiency is a refrigeration system with an evaporator fan control and a smaller wattage circulating fan.

Algorithms

Electric Demand Savings

$\Delta kW = kW_{Fan} \times n_{Fans} \times LRF \times BF$

Symbol Table

Electric Energy Savings

$\Delta kWh = \Delta kW \times 8760$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
8760	=	Hours / Year
BF	=	Bonus factor for reduced cooling load from eliminating heat generated by the evaporator fan inside the cooler or freezer[1] = 1.4 for coolers = 1.8 for freezers = 1.4 for unknown
kW_{Fan}	=	Connected load kW of each evaporator fan motor, based on existing motor type in evaporator fan unit[2]
LRF	=	Load Reduction Factor for motor controlled units (31.3%)[3]
n_{Fans}	=	Number of evaporator fans driven by the controls

Motor Type	kW
Shaded Pole (SP)	0.135
ECM	0.064
Synchronous	0.058
Unknown	0.105

Load Shapes

For Loadshape details, see reference: "EVT_Analysis_Evaporator Fan Motor Control_Mar 2021.xlsx"

68b Evaporator Fan Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
68	Evaporator Fan Control	Active	27.0%	40.0%	14.0%	19.0%	83.1%	83.1%

Net Savings Factors

Measures

RFRFMCON Refrigeration fan motor controls

Tracks [Base Track]

6014PRES [is base track] 6014PRES

Lifetimes

15 years[4]

Measure Cost

The cost for an evaporator fan motor controller including labor is $91 per fan.[5]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Reference Tables

Savings for Evaporator Fan Motor Controls[6]

Energy Savings for Evaporator Fan Motor Controls				
Temperature Range	Savings by Motor Type (ΔkWh)			
	SP	ECM	Synchronous	Unknown
Low (<25F)	666	316	286	518
Medium / High (25-40F / 41-65F)	518	246	223	403
Unknown	518	246	223	403

Savings is on a per fan basis, not per controller. A single control unit can control several fans.

Demand Savings for Evaporator Fan Motor Controls				
Temperature Range	Savings by Motor Type (ΔkW)			
	SP	ECM	Synchronous	Unknown
Low (<25F)	0.076	0.036	0.033	0.059
Medium / High (25-40F / 41-65F)	0.059	0.028	0.025	0.046
Unknown	0.059	0.028	0.025	0.046

Savings is on a per fan basis, not per controller. A single control unit can control several fans.

Measure Description	Item Code
Evaporator Fan Motor Controls (ECM) - Low Temp	BES-EFAN-CC1
Evaporator Fan Motor Controls (ECM) - Med/High Temp	BES-EFAN-CC2
Evaporator Fan Motor Controls (ECM) - Unknown	BES-EFAN-CCEU
Evaporator Fan Motor Controls (Sync) - Low Temp	BES-EFAN-CC3
Evaporator Fan Motor Controls (Sync) - Med/High Temp	BES-EFAN-CC4
Evaporator Fan Motor Controls (Sync) - Unknown	BES-EFAN-CCSU
Evaporator Fan Motor Controls (Unknown) - Low Temp	BES-EFAN-CC5
Evaporator Fan Motor Controls (Unknown) - Med/High Temp	BES-EFAN-CC6
Evaporator Fan Motor Controls (Unknown) - Unknown	BES-EFAN-CCUU

Footnotes

[1] Bonus factors as derived in the NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54. The 1.4 unknown case type bonus factor represents a weighted average of low, medium, and high temperature refrigeration types.

[2] The evaporator fan motor wattage is based on motor type efficiencies and output ratings as calculated from power consumption values for walk-in motors from the following analysis file "Evaporator Motors Reference 2017_v4.xlsx", "Savings Table" tab. The original source material is the Northeast Energy Efficiency Partnership (NEEP) Refrigeration Loadshape Report - "Commercial Refrigeration Loadshape Project Final Report", Cadmus, Regional Evaluation, Measurement, and Verification Forum, 2015 (page 87; section 5.1.4). Efficiency values for ECM and Q-Sync evaporator fan motor, as sourced from "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits", Oak Ridge National Laboratory, 2015 (page 1; section 1). The unknown motor type is based on a 31% to 59% ECM/SP split as reported in the 2016 Vermont Business Sector Market Characterization and Assessment Study, Figure 89, pg. 112.. For the Unknown motor type, the 31% split in motor types uses the average of the two high efficiency motor types ECM and Synchronous. For calculation details see reference file "EVT_Analysis_Evaporator Fan Motor Control_Mar 2021.xlsx".

[3] Load reduction factor as reported in NEEP Loadshape Report for evaporator fan motor control units. This is the difference in effective runtime of unctrolled motors and the effective runtime of all control styles for motor controls. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

[4] The 15 year measure life for evaporator fan motor controls is sourced from DEER 2014 effective useful life (EUL) estimates; California DEER 2014 Effective Useful Life Table Update, DEER2014-EUL-table-update_2014-02-05.xlsx.

[5] Evaporator fan control unit cost of $520 is referenced from the NEEP Incremental Cost Study Part 4 spreadsheet as listed for the New England region on a per controller cost basis. See reference "Evaporator Fan Controls_NEEP_ICS4 Final June 23 2015.xlsx", "Summary of Results" tab. Per fan cost is estimated to be $91 per fan based an average of 5.7 fans per controller derived from 2016 EVT Evaporator Fan Motor Control installation data. See reference file "EVT_Analysis_Evaporator Fan Motor Control_Mar 2021.xlsx".

[6] For detailed savings calculations see reference file "Evaporator Fan Motor Control 2017 Update v2.xlsx".

Refrigerant Leak Repair

Measure Number: CI-RFG-LKRPR b
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

Added non-energy GHG savings and updated the assumed baseline and efficient leakage rates.

Referenced Documents

- 2016 Vermont Business Sector Market Characterization and Assessment Study
- VT SF Existing Homes Onsite Report - DRAFT 122117
- U.S. DOE Commercial Refrigeration Savings Potential_Navigant_2009
- Refrigeration Analysis Tool v5f_TRM Test
- EPA Green Chill Profile_Store Profile_June 2011
- EPA Green Chill Financial Impact Calculator
- AHRI_8018_Final_Report
- ARB Refrigerant Data
- Green Chill_Progress Report 2011_09062012
- EVT_Refrigerant Leak Repair_Analysis_May 2021
- IPCC_Chapter08_FINAL

Description

This measure is for the detection and repair of refrigerant leaks in commercial refrigeration systems. Refrigerant leaks can cause refrigeration systems to work harder in order to compensate for the lost refrigerant. This can lead to lower performing equipment and reduced operating efficiencies.

In addition to energy savings, there are a number of non-energy benefits associated with repairing refrigerant leaks. Both air and moisture can potentially infiltrate the system due to loss of refrigerant, adversly affecting a number of components. Refrigerant leaks can also increase the run time of the system and decrease its efficacy; so for systems working to preserve and maintain food quality, severe refrigerant leaks can negatively effect food health and safety.

Refrigerant leaks also have adverse effects on the environment, with refrigerants being a significant contributor to greenhouse gas emissions.

EPA regulations under Section 608 of the Clean Air Act requires commercial sites with refrigeration systems to maintain certain leak mitigation standards. However, small businesses and other commercial operations outside of large grocery stores and supermarkets, not only do not adhere to these EPA standards, but are rarely, if ever, targeted for inspections, resulting in a large portion of commercial refrigeration systems leaking refrigerant and not being properly maintained. This measure, and its affiliated program, is designed to target small commercial businesses such as independent grocery stores and markets, dairy farms, craft breweries, and other small businesses utilizing refrigeration systems to detect refrigerant leaks and repair them.

This measure is only applicable for sites with 100 horsepower or less in total refrigeration compressor capacity, with no individual compressor exceeding 15 horsepower.

Program Type

Calculation Type: Retrofit

Implementation Type: Midstream

Baseline Efficiencies

The baseline is a refrigeration system with an estimated 25% leak rate.[1]

Efficient Equipment

The efficient scenario is a refrigeration system with detected and repaired leaks, with a conservatively estimated 13% leak rate.[2]

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / Hours

Symbol Table

Non-Energy GHG Savings

ΔGHG	= Charge x ΔLeak x GWP

Symbol Table

Electric Energy Savings

ΔkWh	= (Capacity / 1000) x DC_{Comp} x (1 / EER_{Pre} - 1 / EER_{Post}) x Hours
EER_{Pre}	= EER_{Post} x (1 - % EER Improvement)

Symbol Table

Fossil Fuel Savings

N/A

Where:

% EER Improvement	=	Percent improvement of compressor operating efficiency due to repaired leak = 7.5%[6]
ΔGHG	=	Gross customer annual non-energy GHG savings (lbs. CO2e)
ΔkW	=	Gross customer connected load kW savings
ΔkWh	=	Gross customer annual kWh energy savings
ΔLeak	=	Percentage of total charge that leaks from the system on an annual basis. The difference between the baseline and efficient leakage rate. = 12%[4]
Capacity	=	Operating capacity of the compressor in Btu/h See Reference Table for deemed assumptions
Charge	=	Charge of the refrigeration system, in units of mass (lbs) See Reference Table for deemed assumptions
DC_{Comp}	=	Duty cycle of the compressor = 45%[7]
EER_{Post}	=	Energy Efficiency Ratio of the compressor post leak repair See Reference Table for deemed assumptions
EER_{Pre}	=	Energy Efficiency Ratio of the compressor prior to leak repair

		See Reference Table for deemed results
GWP	=	Global warming potential of refrigerant (lbs CO2e / lb refrigerant) = 2,555[5]
Hours	=	Total summation of bin operating hours for the compressor = 8,417 hours[3]

Load Shapes

14a Commercial Refrigeration

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
14	Commercial Refrigeration	Active	33.0%	32.6%	17.0%	17.4%	69.0%	77.2%

Net Savings Factors

Measures

RFRLEAKR	Refrigerant leak repair

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Lifetimes

The measure life is estimated to be 3 years.

Measure Cost

A copy of contractor invoices that detail the work performed to repair the refrigerant leak, as well as additional labor and parts to improve/repair the refrigeration system performance will be used for the incremental cost for this measure.

O&M Cost Adjustments

Refrigeration systems operating at low refrigerant levels work harder and result in excessive wear and tear on the mechanical components like the compressor, which can experience burnout if not properly maintained. O&M cost savings are based on an annual fulfillment of the system's leaked refrigerant. Refrigerant technician labor rates and the material cost of the leaked refrigerant are included in the annual savings estimate.[8]

As routine operation and maintenance is not typically performed by the target participant for this measure, and occurs only when absolutely necessary, typically when the system or certain components are no longer functioning, an additional 15% adder is included in the O&M calculation. This was included in an attempt to capture wear and tear on the refrigeration system due to unmitigated leaks. The 15% added accounts for early burnout of compressors due to increased cycling, and other adverse deterioration of components in the refrigeration system that will require maintenance and early replacement.

Compressor Hp	O&M Cost Savings
1	$36
1.5	$58
2	$72
2.5	$86
3	$107
3.5	$121
4	$135
4.5	$149
5	$163
5.5	$176
6	$190
7	$274
7.5	$287
8	$301
9	$329
10	$357
15	$496

Reference Tables

Default Measure Assumptions

Compressor Hp	Capacity (Btu/h)	EER Pre	EER Post[9]
1	7,033	8.70	9.41
1.5	10,551	8.70	9.41
2	14,067	8.73	9.44
2.5	17,584	9.68	10.46
3	21,100	9.69	10.48
3.5	24,618	10.05	10.86
4	28,134	10.06	10.88
4.5	31,651	10.13	10.95
5	35,167	10.17	10.99
5.5	38,685	10.55	11.40
6	42,201	10.55	11.40
7	49,234	10.49	11.34
7.5	52,752	11.08	11.98
8	56,268	11.03	11.92
9	63,301	10.95	11.84
10	70,335	10.24	11.07
15	105,502	10.10	10.92

Deemed Energy and Demand Savings

Compressor Hp	Item Code	Deemed Demand Savings (ΔkW)	Deemed Energy Savings (ΔkWh)
1	RFRLEAKRPR1	0.0274	231
1.5	RFRLEAKRPR15	0.0412	347
2	RFRLEAKRPR2	0.0545	459
2.5	RFRLEAKRPR25	0.0609	513
3	RFRLEAKRPR3	0.0739	622
3.5	RFRLEAKRPR35	0.0822	692
4	RFRLEAKRPR4	0.0948	798
4.5	RFRLEAKRPR45	0.1053	886
5	RFRLEAKRPR5	0.1161	977
5.5	RFRLEAKRPR55	0.1231	1,036
6	RFRLEAKRPR6	0.1343	1,130
7	RFRLEAKRPR7	0.1583	1,332
7.5	RFRLEAKRPR7.5	0.1610	1,355
8	RFRLEAKRPR8	0.1714	1,443
9	RFRLEAKRPR9	0.1956	1,646

10	RFRLEAKRPR10	0.2318	1,951
15	RFRLEAKRPR15	0.3530	2,971

Deemend Non-Energy GHG Savings

Compressor Hp	Item Code	Charge Size (lbs of refrigerant)[10]	GHG Savings (lbs of CO2e)
1	RFRLEAKRPR1	7	2,146
1.5	RFRLEAKRPR15	14	4,292
2	RFRLEAKRPR2	14	4,292
2.5	RFRLEAKRPR25	14	4,292
3	RFRLEAKRPR3	20	6,132
3.5	RFRLEAKRPR35	20	6,132
4	RFRLEAKRPR4	20	6,132
4.5	RFRLEAKRPR45	20	6,132
5	RFRLEAKRPR5	20	6,132
5.5	RFRLEAKRPR55	20	6,132
6	RFRLEAKRPR6	20	6,132
7	RFRLEAKRPR7	67	20,542
7.5	RFRLEAKRPR7.5	67	20,542
8	RFRLEAKRPR8	67	20,542
9	RFRLEAKRPR9	67	20,542
10	RFRLEAKRPR10	67	20,542
15	RFRLEAKRPR15	67	20,542

Footnotes

[1] U.S. EPA Green Chill Program, "Profile of an Average U.S. Supermarket's Greenhouse Gas Impacts from Refrigeration Leaks Compared to Electricity Consumption", June 2011

[2] U.S. EPA Green Chill Program, "Progress Report - Green Chill a Partnership at Work", 2011 (pg. 6). To further substantiate the efficient condition leakage rate, supplemental data was pulled from the AHRI report, "AHRI Project 8018 Final Report, Review of Refrigerant Management Programs", Navigant, January 2016. This report includes data suggesting the California Air Resoourced Board (CARB) Refrigerant Management Program has been able to reduce leakage rates to between 9% and 17%. These two sources, therefore, suggest that an average leakage rate of 13% is a reasonable assumption for post-correction "efficient" conditions.

[3] The compressor operating hours are based on a weighted average of walk-in cold storage applications and sites utilizing economizers. If a site leverages a refrigeration economizer, the compressor will not operate at outdoor air temperatures 4°F below the cold storage set temperatures. The weighting for sites with economizers is sourced from the "2016 Vermont Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 109). The weighting for the cold storage applications and associated average refrigeration set temperature is sourced from "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration", U.S. DOE, Navigant, 2009 (page 68). For more information on how the compressor operating hours were binned across the different outdoor air temperatures, please see "EVT_Refrigerant Leak Repair_Analysis_May 2021.xlsx".

[4] The leakage rate improvement, or change in leakage rate, is calculated as the difference between the baseline leakage rate, 25%, and the improved, or efficient, leakage rate of 13%.

[5] The global warming potential of refrigerant represents an average of the most common refrigerants seen in commercial systems in Vermont. This weighting is based on engineering judgement and the refrigerants averaged are; R407C, R407A, R134a, R404a, and R507. GWP100 values were used to calculate the average, which was sourced from the "Intergovernmental Panel on Climate Change (IPCC), Climate Change 2013: The Physical Science, Chapter 8: Anthropagenic and Natural Radiative Forces, Appendix 8.A: Lifetimes, Radiative Efficiencies, and Metric Values" (pg. 731 - 738). For more detail on the refrigerant weighting, please see the 'Notes' tab in the file: "EVT_Refrigerant Leak Repair_Analysis_May 2021.xlsx."

[6] Compressor EER improvement, as a result of repairing a refrigerant leak, is based on a binned weather analysis of an average refrigeration system. The compressor EER varies depending on the outdoor air and condensing temperature. For the pusposes of this characterization, the energy savings associated with the leak repair were summed across different temperature bin and realized in a % improvement of the compressor's operating condition. The EER multipliers at the varying bins, which were used to determine the reduced effects of the compressor at higher outdoor air and condensing temperatures, were taken as a straight average from the EVT's custom refrigeration analysis tool, "Refrigeration Analysis Tool_v5f_TRM Test.xlsm". Where the pre- and post- analysis varies is in the condensing set point. While both leverage a saturated suction temperature of 20°F, the saturated condensing temperature is perpetually 5°F higher in the pre-retrofit scenario as compared to the post-retrofit scenario. This assumption is based on the fact that a loss of refrigerant will cause reductions in both the discharge and suction pressure. As a result, this leads to a lower evaporator temperature causing the compressor to work more and more inefficiently in order to increase the temperature of the refrigerant in order to dissapate heat in the condenser. For practical purposes for this measure, a 5°F increase was assumed for the pre-retrofit suction condensing temperature.

[7] The average compressor duty cycle is 45%, based on a compressor full load operation of 3,910 hours. This value is sourced from EVT's custom refrigeration analysis tool, "Refrigeration Analysis Tool_v5f_TRM Test.xlsm".

[8] The cost per pound of refrigerant ($6.83/lb) is sourced from the EPA Green Chill Program Financial Calculator for Supermarkets (https://www.epa.gov/greenchill/greenchill-resources-and-reports). The labor cost associated with adding refrigerant to a depleted system is based on an hourly refrigerant technician rate of $165 per hour, as quoted by Turner Piping and Refrigeration, a refrigeration service contractor based in Rutland, VT. It was estimated that this service would require 15 minutes per system ton.

[9] The post-retrofit EER is based on the actual rated compressor EER, assuming post leak repair the system resumes its rated operating performance. The value is sourced from leveraging default baseline EER values from the Refrigeration Analysis Tool (see "Refrigeration Analysis Tool_v5f_TRM Test.xlsm") for the specified system capacity range and weighting based on cooler and freezer saturation. Opted to average across single and three phase systems. For more detail on the weighting of refrigeration system type, see the 'Bin Savings' tab in 'EVT_Refrigerant Leak Repair_Analysis_May 2021.xlsx"

[10] Refrigerant system charge is sourced from Heatcraft compressor cut sheets. For more information please see: "EVT_Refrigerant Leak Repair_Analysis_May 2021.xlsx."

Plate Coolers for Dairy Farms

Measure Number: CI-RFG-PLATE c
Portfolio: EVT TRM Portfolio 2020-06
Status: Active
Effective Date: 2020/1/1
End Date: 2023/12/31
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

Reactivated this measure and provided the following updates:

- Developed new algorithms to calculate savings based on the quantity of milk production. The measure was previously based on a deemed tiered system developed from analysis of 51 custom projects from 2003 through 2012. The tiered system had two bins and was based on the number of milking cows on the farm. As the energy savings are dependent on the amount of milk yield, the measure was re-developed to increase accuracy and mitigate risks.
- Made subsequent updates to the measure description, measure life, and footnotes.
- Opted to leverage the existing incremental costs as they are a good representation of the dairy equipment market in Vermont, which has stayed relatively consistent over time.

Referenced Documents

- U.S. DOE_Building America Standard DHW Schedules_May 2014
- Vermont Agriculture Census_2017
- Energy Efficiency for Dairy Enterprises
- EVT_Plate Cooler_Analysis_May 2020_v3

Description

A milk plate cooler is used in dairy applications to pre-cool milk prior to it entering the primary bulk tank refrigeration system. A plate cooler is a heat exchanger used to transfer heat from the milk stream to a stream of ambient temperature water. Electric savings are acheived by reducing the downstream cooling load of the associated refrigerant based system. Generally, there is no opportunity to reclaim heat from the water used in the heat exchange process and it is therefore assumed that this energy is lost. However, Efficiency Vermont encourages farmers to use the plate cooler's warm water to feed cows. Cows prefer to drink warm water and the more water they drink the more milk output they provide, Drinking warmer water is less stressful metabolically for cows and an indirect benefit of this measure is this potential for increased milk production. However, it is recommended that the dairy farm, prior to measure implementation, determine if an adequate supply of water is available for the function of the plate cooler.

On larger dairy farms, plate coolers are generally used in conjunction with a variable speed milk transfer pump to manage flow rate of the milk to ensure optimal heat exchange and reduce refrigeration use even further. For conservative purposes, the energy savings for this measure were developed assuming a variable-speed milk transfer pump is not present on-site. Costs of plate coolers vary greatly based on cooler plate size, therefore the rebate is a tiered rebate, with tiers based on the number of cows as proxy for the volume of milk requiring cooling:

This measure restricts participation for dairy farms with 74 cows or less, as it is not cost-effective for farms with lower milk yields.

Program Type

Calculation Type: Retrofit

Implementation Type: Downstream

Baseline Efficiencies

The baseline state is a milk cooling system where milk is not pre-cooled with a plate cooler, but goes directly into a refrigerated cooling system[1].

High Efficiency

The high efficiency case is installation and use of a plate cooler to pre-cool milk using ambient temperature water prior to refrigerated cooling.

Algorithms

Electric Energy Savings

ΔkWh	$= (\Delta T_{Milk} \times \text{Lbs of Milk} \times C_{p,m} \times \text{Days}) / (\text{EER} \times 1000)$

Symbol Table

Electric Demand Savings

ΔkW	= ΔkWh / Hours

Where:

ΔkW	=	Gross customer connected load kW demand savings
ΔkWh	=	Gross customer annual kWh energy savings
ΔT_{Milk}	=	Change in milk temperature attributable to the plate cooler = 30ºF[2]
1000	=	Conversion factor from watts to kilowatts
$C_{p,m}$	=	Specific heat of milk = 0.93 Btu/lbºF
Days	=	Number of milking days per year = 365 days
EER	=	Efficiency of the existing bulk tank refrigeration compressor[3] = 9.9 EER for reciprocating compressors = 11.1 EER for scroll compressor = 10.5 unknown/other compressor
Hours	=	Annual operating hours = 2,679 hours[4]
Lbs of Milk	=	Quantity of milk produced per day that needs to be cooled. See Reference Tables for deemed values.

Load Shapes

111a Farm Plate Cooler / Heat Recovery Unit

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
111	Farm Plate Cooler / Heat Recovery Unit	Active	29.0%	16.4%	31.6%	23.1%	27.0%	16.1%

Net Savings Factors

Measures

RFRPLATE	Plate cooler

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Lifetimes

The expected measure life of a plate cooler is 15 years.[5]

Measure Cost

The default incremental measure costs are detailed in the table below:

Savings Bin (lbs of milk/day)	Incremental Cost[6]
< 5,100	$2,875
5,101 to 6,800	$2,875
6,801 to 13,600	$6,530
13,601 to 34,000	$6,530
> 34,001	$6,530

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Reference Tables

Deemed Energy and Demand Savings

Compressor Type	Savings Bin (Lbs of Milk/Day)	Average Lbs of Milk/Day	Energy Savings (ΔkWh)	Demand Savings (ΔkW)	Item Code
Reciprocating	< 5,100	4,500	4,629	1.728	RFRPLATEREC1
	5,101 to 6,800	5,951	6,121	2.285	RFRPLATEREC2
	6,801 to 13,600	10,201	10,493	3.917	RFRPLATEREC3
	13,601 to 34,000	23,801	24,483	9.139	RFRPLATEREC4
	> 34,001	34,001	34,975	13.055	RFRPLATEREC5
Scroll	< 5,100	4,500	4,128	1.541	RFRPLATESCR1
	5,101 to 6,800	5,951	5,460	2.038	RFRPLATESCR2
	6,801 to 13,600	10,201	9,359	3.493	RFRPLATESCR3
	13,601 to 34,000	23,801	21,836	8.151	RFRPLATESCR4
	> 34,001	34,001	31,194	11.644	RFRPLATESCR5
Unknown/Other	< 5,100	4,500	4,364	1.629	RFRPLATEUNK1
	5,101 to 6,800	5,951	5,772	2.155	RFRPLATEUNK2
	6,801 to 13,600	10,201	9,894	3.693	RFRPLATEUNK3
	13,601 to 34,000	23,801	23,084	8.617	RFRPLATEUNK4
	> 34,001	34,001	32,976	12.309	RFRPLATEUNK5

Footnotes

[1] While a plate cooler unit would be baseline for a new construction project, farmers typically re-use old equipment when extensively renovating old facilities. New construction for dairy farms in the state of Vermont is rare, and anecdotally, EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

[2] The efficacy of a milk plate cooler is sourced from; Sanford, Scott (University of Wisconsin–Madison), "Energy Efficiency for Dairy Enterprises", Presentation to Agricultural and Life Sciences Program staff, December 2014. It was assumed that there is a 25°F difference in milk temperature for a single pass plate cooler and a 35°F temperature difference for a double/multi-pass plate cooler. For the purposes of this measure characterization, a straight average of 30°F temperature differential between the two types was used. For additional context, a plate cooler reduces the overall load on the refrigeration compressors, and the temperature differential of the milk represents that reduced load.

The 30°F milk temperature differential is also corroborated by the rule of thumb that a plate cooler can reduce the temperature of the milk to within 12°F of the water used in the heat exchanger. The temperature of water being 52°F (Average ground water temperature for Burlington, Montpelier, Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014), the temperature of the milk exiting the plate cooler being 64°F, and the temperature of the milk entering the plate cooler being 94°F, resulting in a milk temperature differential across the plate cooler being 30°F.

[3] Compressor performance data obtained from "Emerson Climate Technologies Product Selection Software Version 1.0.25; Database Date: December 22, 2010." Current OEM or replacement model compressors with capacities from 12,000 Btu/h to 100,000 Btu/h included in simple EER averages. For assumed operating conditions and more detail on the compressor performance data, see: "EVT_Plate Cooler_Analysis_May 2020_v2". Additionally, the unknown/other compressor type category assumes a straight average in the performance data between reciprocating and scroll compressors.

[4] The annual operating hours are based on the EVT Loadshape for Dairy Farm Combined End Uses.

[5] The measure life is sourced from 2014 Database for Energy-Efficiency Resources (DEER), Version 2014.2.04, "Effective/Remaining Useful Life Values", California Public Utilities Commission, February 4, 2014

[6] The incremental costs are sourced from 51 custom EVT projects spanning 2003 through 2012. For more information on is derivation, please see: "EVT_Plate Cooler_Analysis_May 2020_v2.xlsx".

Commercial Reach-In Refrigerators and Freezers

Measure Number: CI-RFG-RIREFR h
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

This update adds Non-Energy Greenhouse Gas savings quantfication to the measure characterization.

Referenced Documents

- Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigeratorFreezer_v3_2.xlsm
- 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values"
- CA_CEUS_COMM_DATA.xlsx
- Itron Inc., "California Commercial End-Use Survey", prepared for California Energy Commission, March 2006.
- ENERGY STAR commercial-kitchen-equipment-calculator-Fridge-Freezer
- evt-commercial-reach-in-refrigerator-and-freezer-analysis-June-2020
- ARB Refrigerant Data
- EVT PIP 124 Refrigerant Management FINAL

Description

The measure described here is a high-efficiency packaged commercial reach-in cooler (refrigerator or freezer) with solid or glass doors, typically used by foodservice establishments, using only natural refrigerants (R-290 and R-600a). This includes one, two and three door reach-in, roll-in/through and pass-through commercial coolers. Beverage merchandisers – a special type of reach-in refrigerator with glass doors – are not included in this characterization. To align with the Vermont commercial kitchen equipment market, the baseline for this measure uses the previous Federal Standard.

Program Type

Calculation Type: Market Opportunity: Time of Sale

Program Delivery/Implementation Type: Downstream

Baseline Efficiencies

The baseline equipment is assumed to be a refrigerator or freezer meeting the minimum federal manufacturing standards as specified by Federal Standards effective January 2010.[1] This baseline is not the current Federal Standard, but is used by the ENERGY STAR Kitchen Appliance Calculator that represents the market baseline found in Vermont today. See the average baseline energy use in the savings table in the Reference Tables section.

Efficient Equipment

A high efficiency reach-in refrigerator or freezer is one that meets the requirements of the ENERGY STAR 4.0 specifications (those meeting the ENERGY STAR specifications as of March 2017). Refer to the Reference Tables section for the detailed specifications. This refrigerator or freezer will have natural refrigerants used in its components.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / Hours

Symbol Table

Non-Energy GHG Savings

ΔGHG	= Charge x Leak x ΔGWP

Symbol Table

Electric Energy Savings

ΔkWh	= kWh_{Base} - kWh_{Eff}

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔGHG	=	Gross customer annual non-energy GHG savings (lbs. CO_2e)
ΔGWP	=	100-year time horizon global warming potential difference between baseline and efficient refrigerants. Units in lbs of Carbon Dioxide Equivalent per lb refrigerant. = 1,295.5[3]
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
Charge	=	Charge of the refrigerant within the system, in units of mass (lbs) = 1.02 lbs[4]
Hours	=	Annual operating hours (8760 hours)[2]
kWh_{Base}	=	Electric energy consumption of a Federal Standard Reach-In Refrigerator or Freezer = Refer to Specifications for Refrigerators and Freezers table below for Baseline Algorithm
kWh_{Eff}	=	Electric energy consumption of a natural refrigerant ENERGY STAR Reach-In Refrigerator or Freezer = Refer to Specifications for Refrigerators and Freezers table below for Efficient Algorithm
Leak	=	Leak rate, expressed as percentage of total refrigerant charge, of the system on an annual basis =2%[5]

Operating Hours

Load Shapes

Commercial Reach-In Refrigerator & Freezer load shape is developed using the California Commercial End-Use Survey.[6]

119a Commercial Reach-In Refrigerator & Freezer

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
119	Commercial Reach-In Refrigerator & Freezer	Active	31.9%	32.3%	17.7%	18.0%	97.9%	118.6%

Net Savings Factors

Measures

RFRCMFZN	Commercial freezer - Natural Refrigerant
RFRCMRFN	Commercial refrigerator - Natural Refrigerant

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	RFRCMFZN	0.95	1.00
6014PRES	6014PRES	RFRCMFZN	0.95	1.05
Pres Equip Rpl	6013PRES	RFRCMRFN	0.95	1.00
6014PRES	6014PRES	RFRCMRFN	0.95	1.05

Persistence

The persistence factor is assumed to be one.

Lifetimes

12 years.[7]

Measure Cost

Based on examination of list prices and price studies performed by others, the determined incremental costs are tabulated below.

Incremental Cost for Refrigerators and Freezer[8]

Incremental Costs			
Door Type	Volume	Refrigerator	Freezer
Solid Door	0 < V < 15	$ 202.63	$ 344.79
	15 ≤ V < 30	$ 511.88	$ 609.58
	30 ≤ V < 50	$ 1,055.03	$ 1,309.79
	50 ≤ V	$ 1,540.92	$ 1,985.74
Glass Door	0 < V < 15	$ 211.96	$ 260.78
	15 ≤ V < 30	$ 506.68	$ 593.85
	30 ≤ V < 50	$ 1,023.15	$ 1,431.97
	50 ≤ V	$ 1,594.27	$ 2,045.00

Note: V = internal volume in cubic feet

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O&M Cost Adjustments

No differences in O&M costs are apparent between the standard and efficient refrigerators.

Reference Tables

Savings for Refrigerators and Freezers[9]

		Refrigerator		Freezer	
Door Type	Volume	ΔkWh	ΔkW	ΔkWh	ΔkW
Solid Door	0 < V < 15	728.3	0.083	733.7	0.084
	15 ≤ V < 30	978.9	0.112	1,980.8	0.226
	30 ≤ V < 50	1,395.1	0.159	4,035.8	0.461
	50 ≤ V	2,136.6	0.244	6,015.4	0.687
Glass Door	0 < V < 15	1,182.4	0.135	1,949.0	0.222
	15 ≤ V < 30	1,452.0	0.166	4,928.3	0.563
	30 ≤ V < 50	1,962.4	0.224	9,222.0	1.053
	50 ≤ V	2,530.7	0.289	13,758.1	1.571

Non-Energy GHG Savings

1.02 lb x 2.0% x 1,295.5 lb CO_2e / lb = **26.4 lb CO_2e**

Note, this value is the same for refrigerators and freezers, regardless of volume.

Specifications for Refrigerators and Freezers

[10][11]

Description and Volume (cu. ft.)	MDECs (Maximum Daily Energy Consumption, kWh/day)			
	Refrigerator		Freezer	
	Baseline	ENERGY STAR 4.0	Baseline	ENERGY STAR 4.0
Solid Door				
0 ≤ V < 15	0.10V+2.04	0.022V+0.97	0.40V+1.38	0.21V+0.90
15 ≤ V < 30		0.066V+0.31		0.12V+2.248
30 ≤ V < 50		0.04V+1.09		0.285V-2.703
50 ≤ V		0.024V+1.89		0.142V+4.445
Glass Door				
0 ≤ V < 15	0.12V+3.34	0.095V+0.445	0.75V+4.1	0.232V+2.36
15 ≤ V < 30		0.05V+1.12		
30 ≤ V < 50		0.076V+0.34		
50 ≤ V		0.105V-1.111		

Note: V = internal volume in cubic feet.

Footnotes

[1] United States Department of Energy, 10 CFR Part 431, *"Energy Conservation Standards for Commercial Refrigeration Equipment"*, Document last updated May, 29, 2020. January 1, 2010 and before March 27, 2017 is the manufacturer applicability date to comply with these standards.

[2] The refrigerator is assumed to always be plugged in and operating 8760 hours per year. This provides an annual average kW demand savings.

[3] The global warming potential of baseline unit refrigerant assumes R-134a, which is considered the most common refrigerant seen in self-contained commercial refrigeratos and freezers. The GWP100 value for R-134a is assumed 1,300, as described by PIP 124. Efficient unit refrigerant is assumed to be either R-290 (Propane) or R-600a (Isobutane), which have GWP100 values of 4 and 5 respectively, per the California Air Resource Board (CARB) Refrigerant Management Program, whose assumptions can be found in the attached file: "ARB Refrigerant Data.xlsx". The average of 4.5 is assumed to derive the difference in refrigerant GWP100 values ------> 1,300 - 4.5 = 1,295.5

[4] The average refrigerant charge of "Stand alone (self-contained) refrig units," sourced from the California Air Resource Board (CARB) Refrigerant Management Program, whose assumptions can be found in the attached file: "ARB Refrigerant Data.xlsx". See cell D16 of worksheet "Refrigerant Leakage." Value used to three significant figures.

[5] Per Program Implementation Plan (PIP) No, 124

[6] Loadshape derived from data in the California Commercial End-Use Survey. Itron Inc., "California Commercial End-Use Survey", prepared for California Energy Commission, March 2006. See reference file "CA_CEUS_COMM_DATA.xlsx". The California Commercial End-Use Survey (CEUS) is a comprehensive study of commercial building sector end-use energy use. Itron performed the survey under contract to the California Energy Commission (CEC), and with the support of Pacific Gas & Electric, San Diego Gas and Electric, Southern California Edison, Southern California Gas Company and the Sacramento Municipal Utility District. A stratified, random sample of 2,800 commercial facilities was targeted and a sample of 2,790 were actually completed. Commercial premises are weighted and aggregated to building segment results.

[7] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008. See reference file "Effective Useful Life EUL_Summary_10-1-08.xls".

[8] Northwest Regional Technical Forum, ENERY STAR Version 4.0 Analysis. Refer to CostData&Analysis tab in ComRefrigeratorFreezer_v4_2.xlsm. These costs include the average cubic foot size from this analysis and applies to the Northwest RTF's average cost per cubic foot. Analysis can be found on Costs tab in EVT Commercial Reach In Refrigerator and Freezer Analysis June 2020.xlsx.

[9] Calculated savings from baseline. See reference: EVT Commercial Reach In Refrigerator and Freezer Analysis June 2020.xlsx.

[10] United States Department of Energy, 10 CFR Part 431, *"Energy Conservation Standards for Commercial Refrigeration Equipment",* January 1, 2010 and before March 27, 2017

[11] ENERGY STAR, *"ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers"*, v4.0, Effective January 1, 2017.

Floating Head Pressure Control

Measure Number:	I-E-12 c
Portfolio:	96
Status:	Active
Effective Date:	2017/1/1
End Date:	[None]
Program:	Commercial & Industrial
End Use:	Refrigeration

Update Summary

- Measure is updated to replace savings deemed by manufacturer compressor listings with recent studies and savings for Floating Head Pressure Controls

Referenced Documents

The main analysis file used as the basis for this measure, RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v1_5.xlsm, 2016 was developed for the Regional Technical Forum (RTF), a technical advisory committee to the Northwest Power and Conservation Council established in 1999 to develop standards to verify and evaluate energy efficiency savings by Portland Energy Conservation, Inc. (PECI).

The work was performed in support of a unitary condensing unit FHP measure developed by PECI for the RTF in 2010.

In attempt to contact PECI for further details about the work it was learned that the original authors no longer work in the same capacity, and furthermore, PECI is no longer responsible for the management of the refrigeration programs for which the workbook originally served.

- DEER2014-EUL-table-update_2014-02-05.xlsx
- RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v1_5.xlsm, 2016
- FHP Savings Extrapolation.xlsx

Description

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90 degrees. By installing a "floating head pressure control" condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that as the outdoor temperature drops, the compressor will not have to work as hard to reject heat from the cooler or freezer. This measure is for the application of floating head pressure controls for compressors ≤ 10HP and a condensing temperature set to 70ºF. This measure is strictly limited to single compressor systems.

Baseline Efficiencies

The baseline is a refrigeration system without floating head pressure control.

Efficient Equipment

High efficiency is a refrigeration system with floating head pressure control.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	= kWh_{HP} × HP

Floating Head Pressure Control kWh Savings per Horsepower (kWh/HP)[2]

Unit Type	Temperature Range		
	Low Temperature (Freezer)	Medium Temperature (Refrigerator)	Unknown Temperature[3]
Self-Contained Unit (SCU)	793	703	732
Remote Condensing Unit (RCU)	636	439	502
Unknown Type[4]	715	571	617

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
HOURS	=	Full load hours (7713 hours)[1]
HP	=	Actual compressor horsepower.
kWh_{HP}	=	kWh per horsepower (value from savings table in Reference Tables section)

Operating Hours

Operating hours that produce savings from a floating head pressure control system will correlate with outside air temperature. When temperatures are below the condensing setpoint, the controls will operate. For a set point of 70ºF , the operating hours are 7713.[1]

Load Shapes

70b Floating Head Pressure Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
70	Floating Head Pressure Control	Active	33.3%	37.1%	12.9%	16.8%	100.0%	0.0%

Net Savings Factors

Measures

RFRFHCON	Refrigeration floating head pressure controls

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	RFRFHCON	0.94	1.00
Cust Equip Rpl	6013CUST	RFRFHCON	0.94	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years.[5]

Measure Cost

Floating Head Pressure Control Costs per Horsepower ($/HP)[6]

Unit Type	Temperature Range		
	Low Temperature (Freezer)	Medium Temperature (Refrigerator)	Unknown Temperature[3]
Self-Contained Unit (SCU)	$296	$390	$360
Remote Condensing Unit (RCU)	$157	$207	$191
Unknown Type[4]	$227	$299	$275

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

Footnotes

[1] Annual average of hours for Vermont that temperature is below 70ºF. This is the condensing temperature that is set for the floating head pressure control as required by EVT. Hours are deemed from TMY3 weather data for Vermont. See "FHP Savings Extrapolation.xlsx" for further details.

[2] Derived from RTF saving estimates for the NW climate zone and extrapolated to Vermont climate zone by using cooling degree-days. RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook *ComGroceryFHPCSingleCompressor_v1_5.xlsm*, 2016.

[3] Unknown values based on weighted average; 2010 ASHRAE Refrigeration Handbook, page 15.1 "Medium- and low-temperature display refrigerator line-ups account for roughly 68% and 32%, respectively, of a typical supermarket's total display refrigerators."

[4] For unit type unknown, it is assumed 50/50 split of self-contained and remote condensing units.

[5] California DEER 2014 Effective Useful Life (EUL) table. See Reference file "DEER2014 EUL Table Update.xlsx".

[6] Costs are based on number of additional valves per condenser motor for different HP ratings and includes installation labor costs. Costs are averaged and shown on a per HP basis. See reference file RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook *ComGroceryFHPCSingleCompressor_v1_5.xlsm*, 2016.

High Efficiency Condensing Units

Measure Number: I-E-14 d
Portfolio:
Status: Active
Effective Date: 2021/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

For 2021, adding fractional compressor horsepower options (0.5 and 0.75 HP), as well as 5.5 and 6.0 HP options to the program. Original TRM supporting work had already established savings and inputs for the larger capacities, but the offering was limited to 5 HP and lower units. Thus, this update is simply expanding the impact summary tables to now show 5.5 and 6.0 HP units. Fractional horsepower options also rely on previous workbooks and are extrapolations.

Referenced Documents

Refrigeration Analysis Tool v5d_Modified for HECU TRM :contains the template of the analysis tool used to establish savings for this measure

Trenton Data & Heatcraft Data: product data sheets from which capacities were derived for analysis

HECU Capacity Inputs and Savings Outputs 2021: outlines the methodology to determine average capacities from product data and summarizes the analysis outputs from the analysis tool

HECU Connected kW Load Savings 2021: shows the derivation of connect load savings for this measure

HECU Compressor Fan Loadshape F: shows the derivation of the custom loadshape developed for HECU compressor fan energy and demand savings

HECU Incremental Costs 2021: outlines the methodology used to establish incremental costs

- Trenton Data
- Heatcraft Data
- Refrigeration Analysis Tool v5d_Modified for HECU TRM
- HECU Compressor Fan Loadshape F
- HECU Incremental Costs 2021
- HECU Connected kW Load Savings 2021
- HECU Capacity Inputs and Savings Outputs 2021

Description

This characterization captures the savings attributed to an upstream commercial refrigeration condensing unit initiative capitalizing on market opportunities to drive the installation of efficient condensing units instead of standard baseline units. Applicable to condensing units serving Low (0°F) and Medium (32°F) conditioned environments, an efficient condensing unit is defined by units incorporating three requisite attributes: an efficient scroll compressor, floating head pressure controls, and modulating compressor fan speed capabilities (for analysis purposes low/high speed capabilities are assumed, however some units are equipped with variable speed drives that would realize additional savings). The collective effect of these three features results in the refrigeration load requirements being met while using less power as compared to a baseline unit. Units with compressor horsepower ratings in the range of 1-6hp are eligible to participate in the upstream initiative. Eligibility is limited to outdoor units. Savings claimed assume the efficient unit replaces a baseline outdoor unit, however it's worth noting that a customer replacing an indoor unit with an outdoor unit would likely realize additional savings.

As illustrated in the following sections, prescriptive deemed savings will be claimed based on a unit's temperature application, power phase requirements and compressor horsepower rating. Of note is that for the purposes of the TRM, horsepower ratings are specific in 1/2 horsepower increments. It it believed that most eligible units will map neatly to an established horsepower category, however in the event a qualifying unit falls somewhere in the middle of an established category, it will be assigned to the closest category with the most conservative total kWh savings.

Baseline Efficiencies

A baseline condensing unit is one with a standard compressor efficiency rating (as defined and established by EVT's Refrigeration Analysis Tool), no floating head pressure controls, and single speed compressor fan motors.

Efficient Equipment

High Efficiency Condensing Units must have scroll compressor technology, incorporate floating head pressure controls, and have the ability to modulate compressor fan speed.

Algorithms

Electric Demand Savings

A full derivation of demand savings is shown in reference file "HECU Connected kW Load Savings." The tabulated energy saving values for each of the three components (scroll compressor, compressor fans, floating head pressure contols) was divided by their respective annual full load operating hours, as described in the following table. **Note that final tabulated savings outcomes for Medium temperature units are a blend to account for installations assumed to occur in systems that have pre-existing economizers installed. The 2016 Vermont Business Sector Market Characterization and Assessment Study (Cadmus, 2017) reports that about 22% of walk-in coolers in EVT territory have economizers. Accounting for the fact that HECUs have many additional applications, including bulks tanks and closed cases for example, where economizer use is not possible, EVT will assume that 10% of installations through the program occur on systems equipped with economizers.**

Component	Annual Full Load Operating Hours	Source
Scroll Compressor	2913.35171232877 (w/Economizer), 3910 (w/o Economizer)	EVT Refrigeration Analysis Tool (CATInput worksheet)
Compressor Fan(s)	6087	As derived in HECU Compressor Fan Loadshape F
Floating Head Pressure Controls	7221	EVT Refrigeration Analysis Tool (CATInput worksheet)

Temp	Phase	HP	Scroll Compressor	Condenser Fan(s)	Floating Head Pressure Controls	Total
Medium	1	0.5	0.11762	0.03342	0.05259	0.20363
		0.75	0.17643	0.05013	0.07888	0.30542
		1	0.21997	0.07605	0.12982	0.42584
		1.5	0.16477	0.08149	0.15421	0.40046
		2	0.19216	0.09504	0.17984	0.46703
		2.5	0.22508	0.11132	0.21065	0.54705
		3	0.21755	0.14153	0.28241	0.64149
		3.5	0.30964	0.16165	0.30956	0.78085
		4	0.34246	0.17879	0.34237	0.86361
		4.5	0.34856	0.18197	0.34847	0.87899
		5	0.25508	0.18916	0.38505	0.82928
		5.5	0.27098	0.20095	0.40906	0.88098
		6	0.29003	0.24856	0.51558	1.05417
	3	0.5	0.08264	0.03017	0.04916	0.16198
		0.75	0.12397	0.04525	0.07375	0.24294
		1	0.15623	0.06806	0.11695	0.34124
		1.5	0.13245	0.07799	0.14330	0.35374
		2	0.15447	0.09095	0.16712	0.41254
		2.5	0.18093	0.10654	0.19576	0.48322
		3	0.18620	0.13028	0.24637	0.56283
		3.5	0.27717	0.14907	0.26912	0.69534
		4	0.30654	0.16487	0.29764	0.76904
		4.5	0.31200	0.16780	0.30294	0.78274
		5	0.27084	0.18512	0.34883	0.80477
		5.5	0.28773	0.19666	0.37058	0.85496
		6	0.30695	0.22553	0.42958	0.96205
		0.5	0.02888	0.02241	0.04157	0.09286
		0.75	0.04332	0.03362	0.06236	0.13930
		1	0.05776	0.04482	0.08315	0.18574

Low	1	1.5	0.08895	0.06433	0.11805	0.27134
		2	0.12604	0.09116	0.16728	0.38449
		2.5	0.11317	0.10645	0.20257	0.42219
		3	0.12627	0.11877	0.22601	0.47105
		3.5	0.15284	0.14376	0.27357	0.57016
		4	0.14442	0.14687	0.28200	0.57329
		4.5	0.15564	0.15828	0.30390	0.61783
		5	0.17356	0.17651	0.33889	0.68896
		5.5	0.23952	0.19129	0.35632	0.78712
		6	0.28600	0.22841	0.42547	0.93988
	3	0.5	0.02388	0.02036	0.03782	0.08206
		0.75	0.03582	0.03054	0.05673	0.12310
		1	0.04776	0.04073	0.07564	0.16413
		1.5	0.06397	0.05854	0.10972	0.23224
		2	0.09065	0.08296	0.15547	0.32908
		2.5	0.09374	0.09918	0.18896	0.38187
		3	0.10458	0.11065	0.21082	0.42606
		3.5	0.12659	0.13394	0.25518	0.51571
		4	0.15581	0.14292	0.26794	0.56668
		4.5	0.16792	0.15403	0.28875	0.61070
		5	0.18725	0.17176	0.32200	0.68101
		5.5	0.24354	0.18914	0.34672	0.77940
		6	0.29081	0.22584	0.41401	0.93066

Electric Energy Savings

As described in full detail in the reference file "Refrigeration Analysis Tool v5d_Modified for HECU TRM" savings for High Efficiency Condensing Units were established by running iterations in EVT's Refrigeration Analysis Tool, with considerations for differences in refrigeration temperature environment, capacity, single or three-phase power requirements, and the existence of an economizer. For the pruposes of screening and, the savings for each componend will be treated separately against its respective loadshape, as described in the Load Shapes section below. The following table outlines the energy savings (kWh) associated with each specified unit:

Temp	Phase	HP	Scroll Compressor	Condenser Fan(s)	Floating Head Pressure Controls	Total
Medium	1	0.5	448.2	203.4	379.7	1031.3
		0.75	672.2	305.1	569.6	1547.0
		1	838.1	462.9	937.5	2238.5
		1.5	627.8	496.0	1113.5	2237.4
		2	732.2	578.5	1298.6	2609.3
		2.5	857.6	677.6	1521.1	3056.3
		3	828.9	861.5	2039.3	3729.7
		3.5	1179.8	984.0	2235.4	4399.1
		4	1304.9	1088.3	2472.3	4865.4
		4.5	1328.1	1107.7	2516.3	4952.1
		5	971.9	1151.4	2780.5	4903.8
		5.5	1032.5	1223.2	2953.8	5209.5
		6	1105.1	1513.0	3723.0	6341.1
	3	0.5	314.9	183.6	355.0	853.5
		0.75	472.3	275.4	532.5	1280.3
		1	595.3	414.3	844.5	1854.1
		1.5	504.7	474.7	1034.8	2014.2
		2	588.6	553.6	1206.8	2349.0
		2.5	689.4	648.5	1413.6	2751.4
		3	709.4	793.0	1779.0	3281.5
		3.5	1056.0	907.4	1943.3	3906.7
		4	1168.0	1003.5	2149.3	4320.8
		4.5	1188.8	1021.4	2187.6	4397.8
		5	1032.0	1126.8	2518.9	4677.6
		5.5	1096.3	1197.1	2675.9	4969.3
		6	1169.5	1372.8	3102.0	5644.4
Low	1	0.5	119.5	136.4	300.2	556.2
		0.75	179.3	204.6	450.3	834.3
		1	239.1	272.8	600.4	1112.3
		1.5	368.1	391.6	852.5	1612.2
		2	521.7	554.9	1208.0	2284.5
		2.5	468.4	648.0	1462.8	2579.2
		3	522.6	722.9	1632.0	2877.6
		3.5	632.6	875.1	1975.4	3483.1
		4	597.8	894.0	2036.3	3528.1
		4.5	644.2	963.5	2194.5	3802.2
		5	718.4	1074.4	2447.1	4239.9
		5.5	991.4	1164.4	2573.0	4728.7
		6	1183.7	1390.3	3072.3	5646.4
	3	0.5	98.8	123.9	273.1	495.9
		0.75	148.3	185.9	409.7	743.8
		1	197.7	247.9	546.2	991.8
		1.5	264.8	356.4	792.3	1413.4
		2	375.2	505.0	1122.7	2002.8
		2.5	388.0	603.7	1364.5	2356.1
		3	432.9	673.5	1522.3	2628.7
		3.5	523.9	815.3	1842.7	3181.9
		4	644.9	870.0	1934.8	3449.7
		4.5	695.0	937.6	2085.1	3717.7
		5	775.0	1045.5	2325.1	4145.7
		5.5	1008.0	1151.3	2503.7	4663.0
		6	1203.6	1374.7	2989.6	5567.9

Fossil Fuel Savings

Not applicable.

Load Shapes

Loadshape 14a will be used to capture the coincident peak energy and demand savings attributed to the energy savings associated with the scroll compressor.

Loadshape 70a will be used to capture the coincident peak energy and demand savings attributed to the energy savings associated with floating head pressure controls.

The custom loadshape described below will be used to capture the coincident peak energy and demand savings attributed to low speed compressor fan operation. A full derivation of this loadshape is available in the reference file "HECU Compressor Fan Loadshape F".

Energy				Demand		FLH
Winter Peak	Winter Off-Peak	Summer Peak	Summer Off-Peak	Winter	Summer	
Oct-May, 7am-11pm, M-F	Oct-May, Weekends all day and 11pm-7am, M-F	Jun-Sept, 7am-11pm, M-F	Jun-Sept, Weekends all day and 11pm-7am, M-F	Dec-Jan, 5pm-7pm, M-F, non-holiday	Jun-Aug, 1pm-5pm, M-F, non-holiday	
40.09%	47.99%	4.09%	7.84%	100.00%	1.15%	6087.00

14a Commercial Refrigeration
70b Floating Head Pressure Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
14	Commercial Refrigeration	Active	33.0%	32.6%	17.0%	17.4%	69.0%	77.2%
70	Floating Head Pressure Control	Active	33.3%	37.1%	12.9%	16.8%	100.0%	0.0%

Net Savings Factors

Measures

RFROHECU	Outdoor High Efficiency Condensing Unit

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Lifetimes

The expected measure life is 13 years, consistent with EVT's custom refrigeration analysis assumptions for a scroll compressor.

Measure Cost

Incremental costs are established based on compressor horsepower rating, as indicated in the following table[1]:

Horsepower	Incremental Cost
0.5	$52.10
0.75	$126.30
1.0	$200.50
1.5	$348.90
2.0	$600.00
2.5	$586.50
3.0	$573.00
3.5	$899.00
4.0	$1225.00
4.5	$1298.50
5.0	$1372.00
5.5	$1536.10
6.0	$1684.50

Footnotes

[1] On August 21, 2017 several Efficiency Vermont staff members met with FW Webb representatives in Rutland, VT. Representing FW Webb were 2 General Managers (Darrell Read and Brian Bradley) as well as the Director of Refrigeration (Rich Boynton) and Business Development Manager (Chuck Fiorino). During this meeting, cost information comparing standard (non-controlled, hermetic compressor) condensers and premium efficiency condensers (floating head pressure controls and scroll compressors) was shared for compressors rated at 2,3,4 and 5 horsepower. The costs for other capacities were extrapolated per the methods outlined in the referenced document "HECU Incremental Costs.xlsx".

Refrigerated Case Covers

Measure Number: I-E-2 c
Portfolio: 93
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

- Measure updated to utilize the U.S. Department of Energy, Energy Conservation Standards for Commercial Refrigeration Equipment Engineering Spreadsheet
- Measure updated to utilize more recent Measure Cost and case cover efficiencies

Referenced Documents

- Northwest Regional Technical Forum, Commercial Grocery Strip Curtain analysis, 2016. "ComGroceryStripCurtain_v1_6.xlsm".
- PG&E, "Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases)", Work Paper PGECOREF101, July 2014.
- PG&E, "Strip Curtains for Doorways to Refrigerated Storage", Work Paper PGECOREF103, May 2012.
- EVT Refrigeration Analysis Tool v5b
- Refrigerated Case Covers Study 2016 v2.xlsx

Description

By covering refrigerated cases, the heat gain due to the spilling of refrigerated air and convective mixing with room air is reduced at the case opening. Strip curtains can be deployed continuously and allow the customer to reach through the curtain to select the product. Continuous curtains can be pulled down overnight while the store is closed. Strip curtains are not used for low temperature, multi-deck applications. Glass door retrofits are a better choice for these applications.

Algorithms

Electric Demand Savings

$\Delta kW = (HG \times EF \times CL \times DF) / (EER \times 1000)$

Symbol Table

Electric Energy Savings

$\Delta kWh = \Delta kW \times Usage \times 365$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
1000	=	Conversion from watts to kW (W/kW)
365	=	Days / Year
CL	=	Refrigerated case length in feet (ft). Case length is the open length of the refrigerated box. If the unit is two sided use the open length of both sides.
DF	=	Disabling Factor to account for the portion of the time that the strip curtain is intentionally disabled, as well as time to access the product. The Disabling factor is assumed to be 80% for strip curtains and 100% for continuous case covers.[1]
EER	=	Compressor efficiency (Btu/hr-watt). The average compressor efficiency (EER) is 11.36 for medium temperature applications (case temperature 10°F to 40°F) and 17.7 for high temperature applications (case temperature 45°F to 65°F).[2]
EF	=	Efficiency Factor: Fraction of heat gain prevented by case cover. The Efficiency Factor for strip curtains is 0.82.[3] The Efficiency Factor for continuous covers is 0.50.[4]
HG	=	Loss of cold air or heat gain for refrigerated cases with no cover (Btu/hr-ft opening). The heat gain is 734 for open cooler applications.[5]
Usage	=	Average hours per day that case cover is in place (hrs/day). Assume 24 hrs/day for strip curtains. Assume 8 hours per day for continuous covers.

Baseline Efficiencies

The baseline condition is a refrigerated case without a cover.

Efficient Equipment

High efficiency is a refrigerated case with a strip curtain or night cover.

Load Shapes

Source: Strip curtain uses the same energy distribution as the previously-developed commercial refrigeration loadshape in Vermont State Cost-Effectiveness Screening Tool. Coincident factors for strip curtains are set at 100% since the calculated kW savings is an average for every hour. The night case covers loadshape is based on the savings occurring from 11 PM to 7 AM.

67a Strip Curtain
77a Refrigeration Night Covers

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
67	Strip Curtain	Active	33.0%	32.6%	17.0%	17.4%	100.0%	100.0%
77	Refrigeration Night Covers	Active	6.0%	60.6%	3.0%	30.4%	0.0%	0.0%

Net Savings Factors

Measures

RFRCOVER	Refrigerator covers

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	RFRCOVER	0.95	1.00

6014PRES	6014PRES RFRCOVER	0.95	1.05

Persistence
The persistence factor is assumed to be one.

Lifetimes
Strip curtains: 4 years

Continuous covers: 5 years

Measure Cost
Typically costs are approximately $42/ft for continuous curtains[4] and $40/ft for strip curtains.[6]

O&M Cost Adjustments
Strip curtains require regular cleaning -- $4.33/yr-ft (1 minute/foot every two weeks at $10/hr).

Continuous curtains require that they are pulled down nightly – $2.53/yr-ft (5 sec. per 4-foot section, twice per day, at $10/hr)[7]

Fossil Fuel Descriptions
There are no fossil fuel algorithms or default values for this measure.

Water Descriptions
There are no water algorithms or default values for this measure.

Reference Tables
Demand and Energy Savings for Strip and Continuous Refrigeration Covers[8]

	Refrigerated Space Temperature			
Cover Type	Medium Temp (10°F to 40°F)		High Temp (45°F to 65°F)	
	Demand Savings (ΔkW/ft)	Annual Energy Savings (ΔkWh/ft)	Demand Savings (ΔkW/ft)	Annual Energy Savings (ΔkWh/ft)
Strip Curtains	0.041	363	0.027	238
Continuous (Night Cover)	0.032	92	0.021	61

Footnotes
[1] TAG agreement established January 2006. Reviewed June 2016.

[2] Average EER values were calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and saturated suction temperatures (SST) of 20°F for medium temperature applications and 45°F for high temperature applications. EER is developed in EVT "Refrigeration Analysis Tool v5b", as seen on the 'Overall EERs' sumamry tab. Values are developed using data from Emerson Climate Technology software. Last updated November 2013.

[3] Calculated from the average effectiveness against infiltration or reduction of heat infiltration pre and post strip curtain installation. Derived in Northwest Regional Technical Forum, Commercial Grocery Strip Curtain analysis, 2016. See reference file "ComGroceryStrip_v1_6.xlsm". Values on tab "Cooling Load Calc".

[4] PG&E, "Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases)", Work Paper PGECOREF101, July 2014. Page 7, Section 4.3.

[5] Calculated from the average baseline (no cover) infiltration of commercial coolers. Derived in Northwest Regional Technical Forum, Commercial Grocery Strip Curtain analysis, 2016. See reference file "ComGroceryStrip_v1_6.xlsm". Value on tab "Cooling Load Calc".

[6] Cost per linear foot derived with the assumption that a typical display case merchandise cooler has an internal height of 4 feet and costs per square foot is $10 as listed in the following reference. PG&E, "Strip Curtains for Doorways to Refrigerated Storage", Work Paper PGECOREF103, May 2012. Page 31, Section 4.3.

[7] Labor rate of $10/hour is effective in the state of Vermont as of January 1, 2017. Rate is based on Vermont Department of Labor, "Establishment of Minimum Wage", Section 384, Chapter 5, Title 21, Subsection (a).

[8] For detailed calculation of demand and energy savings see reference file "Refrigerated Case Covers Study 2016 v2.xlsx"

ENERGY STAR Commercial Ice Makers

Measure Number: I-E-5 e
Portfolio: EVT TRM Portfolio 2018-09
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

Update to the baseline to reflect the federal standard effective in January 2018, to the efficient criteria to reflect the ENERGY STAR 3.0 specification, and to the incremental cost.

Referenced Documents

- "A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify
- 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Use
- EPA_Commercial Kitchen Equipment Calculator_Oct 2016
- evt-energy-star-commercial-ice-makers-analysis-mar-2019

Description

This measure relates to the installation of a new ENERGY STAR-qualified commercial continous ice machine. This measure applies to air-cooled, cube-type machines including ice-making head, self-contained, and remote-condensing units and excludes flake and nugget type ice machines. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building. This measure excludes batch type ice makers.

This measure was developed to be applicable to the following program types: TOS and NC. If applied to other program types, the measure savings should be verified.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / (HOURS × DC)

Symbol Table

Electric Energy Savings

ΔkWh	= $((kWh_{base} - kWh_{ee})/ 100) \times (DC \times H) \times 365$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
100	=	Factor to convert kWhbase and kWhee into maximum kWh consumption per pound of ice
365	=	Days per year
DC	=	Duty cycle of the ice machine[1] 0.57
H	=	Harvest Rate (pounds of ice made per day) For assumed harvest rates use to calculate kW and kWh savings, see reference table #2 below
HOURS	=	Annual operating hours[2] 8760
kWh_{base}	=	Maximum kWh consumption per 100 pounds of ice for the baseline equipment Calculated using the algorithms in reference table #1 below and the assumed harvest rate (H) of the efficient equipment. See reference table #2 for calculated kWh_{base} values.
kWh_{ee}	=	Maximum kWh consumption per 100 pounds of ice for the efficient equipment Calculated using the algorithms in reference table #1 below and the assumed harvest rate (H) of the efficient equipment. See reference table #2 for calculated kWh_{ee} values.

Baseline Efficiencies

The baseline equipment is assumed to be a commercial ice machine meeting federal equipment standards effective on January 28, 2018.

High Efficiency

The efficient equipment is assumed to be a new commercial continuous ice machine meeting the minimum ENERGY STAR Version 3.0 efficiency level standards.

Load Shapes

14a Commercial Refrigeration

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
14	Commercial Refrigeration	Active	33.0%	32.6%	17.0%	17.4%	69.0%	77.2%

Net Savings Factors

Measures

RFRCOMIM	Commercial icemaker

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[3]

Measure Cost

The incremental capital cost for this measure is $222.[4]

O&M Cost Adjustments

No differences in O&M costs are apparent between standard and efficient ice makers.

Fossil Fuel Description

There are no fossil fuel algorithms or default values for this measure.

Water Descriptions

While the ENERGY STAR labeling criteria require that certified commercial ice machines meet certain "maximum potable water use per 100 pounds of ice made" requirements, such requirements are intended to prevent equipment manufacturers from gaining energy efficiency at the cost of water consumptions. A review of the AHRI Certification Directory[5] indicates that approximately 81% of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement. Therefore, there are no assumed water impacts for this measure.

Reference Tables

Reference Table #1

Algorithms for Calculating kWh_{base} and kWh_{ee}[6]

Equipment Type	Harvest Rate lb ice/24 hours	Algorithm for kWh_{base} (kWh/100 lb ice)	Algorithm for kWh_{ee} (kWh/100 lbs ice)
Ice-Making Head	<310	9.19-0.00629H	7.90-0.005409H
Ice-Making Head	>=310 and <820	8.23-0.0032H	7.08-0.002752H
Ice-Making Head	>=820 and <4000	5.61	4.82
Remote Condensing (but not remote compressor)	<800	9.7-0.0058H	7.76-0.00464H
Remote Condensing (but not remote compressor)	>=800 and <4000	5.06	4.05
Self-Contained	<200	14.22-0.03H	12.37-0.0261H
Self-Contained	>=200 and <700	9.47-0.00624H	8.24-0.005429H
Self-Contained	>=700 and <4000	5.1	4.44

Reference Table #2

Annual Electric Energy and Demand Savings per Ice Machine [7]

Equipment Type	Harvest Rate lb ice/24 hours	Assumed Harvest Rate	kWhbase	kWhee	ΔkWh	ΔkW
Ice-Making Head	>=310 and <820	581	6.37	5.48	1076.5	0.22
Ice-Making Head	>=820 and <4000	899	5.61	4.82	1478.1	0.30
Remote Condensing (but not remote compressor)	<800	572	6.38	5.11	1512.4	0.30
Remote Condensing (but not remote compressor)	>=800 and <4000	2012	5.06	4.05	4230.7	0.85
Self-Contained	<200	152	9.65	8.39	399.6	0.08
Self-Contained	>=200 and <700	319	7.48	6.51	644.2	0.13

Footnotes

[1] Duty cycle varies considerably from one installation to the next. A field study of eight ice machines in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007).

[2] Unit is assumed to be connected to power 24 hours per day, 365 days per year.

[3] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.

[4] Incremental cost for continuos-type machines from ENERGY STAR Commercial Kitchen Equipment Savings Calculator. Calculator cites EPA research using AutoQuotes, 2016.

[5] AHRI Certification Directory, Accessed on 7/7/10.

[6] Algorithms from federal equipment standards and ENERGY STAR specifications for commercial ice makers.

[7] Refer to analysis document EVT_Commercial Ice Maker_Analysis_Sept 2018.xlsx. Average assumed ice harvest rate based on average of bins in ENERGY STAR commercial kitchen equipment calculator.

Evaporator Fan Motors

Measure Number:	I-E-8 e
Portfolio:	EVT TRM Portfolio 2017-11
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Commercial & Industrial
End Use:	Refrigeration

Update Summary

- Measure updated to aggregate characterizations across temperature range and baseline motor for Brushelss DC Motors in both Case Cooler and Walk-In applications.
  - Incorporated participation data through 2016 which made very minor revisions to the Synchrnous motor prescriptive savings due to changes to the weighted averages.
  - Uploaded the revised workbook, "evaporator-motors-reference-2017-v4.xlsx" replacing the older version, "evaporator-motors-reference-2016-v3.xlsx". Updated the references throughout the characterization as well.
  - Made subsequent edits to the Description section, which discuss the reason for the characterization aggregation (adding measure to midstream program) and how the characterization was performed.

Referenced Documents

- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Navigant, "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", 2013.
- Oak Ridge National Laboratory, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits", 2015.
- AESC Inc., "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators", 2016.
- DEER2014-EUL-table-update_2014-02-05.xlsx
- NEEP, "Q-SyncMotors.xlsx", 2016.
- Evaporator Motors Reference 2017_v4

Description

Refrigerator and Freezer walk-in unit evaporator fans typically contain two to twelve evaporator fans that run nearly 24 hours each day, 365 days each year. Not only do these fans use electricity, but the heat that each fan generates must also be removed by the refrigeration system to keep the product cold, adding more to the annual electricity costs. If the cooler or freezer has single-phase power, the electricity usage can be reduced by choosing brushless DC (BDC) motors or permanent magnet synchronous motors (Sync) instead of conventional shaded-pole (SP) and permanent split capacitor (PSC) motors. Brushless DC motors are also known by the copyrighted trade name ECM (Electronically Commutated Motor).

In 2016, synchronous motors have been added to Efficiency Vermont's Upstream Refrigeration Program. Synchronous motors are not tracked through a typical Commercial Refrigeration Rebate Form. Prescriptive savings for synchronous motors have been estimated using historical Efficiency Vermont data. See reference tables below.

In 2017, brushless permanent magnet motors (also known as ECM) have been added to Efficiency Vermont's EEFM Midstream Program. Similar to sychronous motors, prescriptive savings for BPM motors have been estimated using historical Efficiency Vermont data and aggregated across temperature ranges and replacement/baseline motor.

Algorithms

Electric Demand Savings

ΔkW	$= (kW_{Base} - kW_{Eff}) \times DC_{Evap} \times BF$
kW_{Base}	$= W_{Base\_Out} \times (1/\eta_{Base}) / 1000$
kW_{Eff}	$= W_{Eff\_Out} \times (1/\eta_{Eff}) / 1000$

Symbol Table

Electric Energy Savings

ΔkWh	$= \Delta kW \times 8760$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
η_{Base}	=	Baseline motor efficiency, 0.26 for SP/0.40 for PSC[1]
W_{Base_Out}	=	Rated watt output of baseline motor, 12 watts for cases/42 watts for walk-in applications[2]
η_{Eff}	=	New motor efficiency, 0.66 for BDC/0.73 for Sync[3]
1000	=	Convert watts to kilowatts (W/kW)
8760	=	Hours / Year
BF	=	Bonus factor for reduced cooling load from eliminating heat generated by the evaporator fan inside the cooler or freezer (1.4 for coolers, 1.8 for freezers)[4]
DC_{Evap}	=	Duty cycle of the evaporator fan, 97.8%[5]
kW_{Base}	=	Electrical demand of the baseline motor
kW_{Eff}	=	Electrical demand of the efficient motor
kW_{Eff}	=	
W_{Eff_Out}	=	Rated watt output of efficient motor, 12 watts for cases/42 watts for walk-in applications

Baseline Efficiencies

The baseline condition is shaded pole or permanent split capacitor evaporator fan motor.

Efficient Equipment

High efficiency is a brushless DC or synchronous evaporator fan motor.

Operating Hours

A cooler evaporator fan runs all the time or 8760 hours per year. A freezer evaporator fan runs 8550 hours per year due to defrost cycles.[2] The smaller number of hours for freezer fan run time is captured in the duty cycle factor in the ΔkW calculation, so that 100% coincidence factors may be applied to both applications.

Load Shapes

Evaporator fan loadshape was reassessed using results and data from the Cadmus NEEP Loadshape report. For evaluation details see the reference file "Evaporator Motors Reference 2017 v4.xlsx", 'Cadmus Loadshape 2015' tab.

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7%	34.9%	15.9%	17.5%	100.0%	100.0%

Net Savings Factors

Measures

RFRBLFAN	Efficient blower fan
RFRSYFAN	Synchronous Motor Evaporator Fan

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6013UPST [is base track]	Upstream - Commercial
6014PRES [is base track]	6014PRES

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years[6]

Measure Cost

Retrofit cost are shown below for brushless DC and synchronous motors applied in both case and walk-in applications.[7]

Evaporator Fan Retrofit Costs

Application	Motor Type	
	Brushless DC	Synchronous
Case	$114	$120
Walk-In	$143	$145

Cost of retrofit includes installation

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Reference Tables

Motor Savings for Evaporator Fans

Measure	Temperature Range	Baseline Motor	Case Cooler		Walk-In Coolers	
			Demand Savings kW/motor	Energy Savings kWh/year	Demand Savings kW/motor	Energy Savings kWh/year
Brushless Permanent Magnet Motor	Low/Medium/High	SP/PSC	0.04	308	0.10	899
Synchronous Motor	Low/Medium/High*	SP/PSC*	0.04	322	0.10	904

*Weighted average Bonus Factor (1.33/1.33) and baseline motor efficiency (0.27/0.31) derived from Efficiency Vermont motor installations for Case/Walk-In applications respectively. See reference file: Evaporator Motors Reference 2017 v4.xlsx.

Footnotes

[1] Efficiencies were determined using an average of baseline motor efficiencies from the following reports. Navigant, "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", 2013. Page 5, Table 2.1. Oak Ridge National Laboratory, *"Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits"*, 2015. Page 1, Section 1.

[2] Motor wattage derived using motor type efficiencies and output ratings. Calculated power consumption comparable to NEEP loadshape reported values for baseline walk-in motors. For calculation details see reference file "Evaporator Motors Reference 2017 v4.xlsx", "Savings Table" tab. NEEP values for reference from The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 87, Section 5.1.4.

[3] Oak Ridge National Laboratory, *"Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits"*, 2015. Page 1, Section 1.

[4] Bonus factors as derived in the NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54.

[5] An evaporator fan runs on average 8567 hours per year, 97.8% of the full 8760 hours per year, due to defrost cycles. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

[6] DEER 2014 effective useful life (EUL) estimates. California DEER 2014 Effective Useful Life Table Update, DEER2014-EUL-table-update_2014-02-05.xlsx

[7] Costs are determined from manufacturer quotes and listings. See reference files Evaporator Motors Reference 2017 v4.xlsx, NEEP Incremental Cost Study – Emerging Technology, Q-SyncMotors.xlsx, 2016; AESC Inc., *"Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators"*, 2016. Page 26.

Refrigerator/Freezer Early Retirement

Measure Number: IV-B-3 c
Portfolio: EVT TRM Portfolio 2017-10
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Refrigeration

Update Summary

Savings from early retirement of refrigerators and freezers has been recalculated using the last year of data from the EVT program (2015) and using an updated IL regression model.

This measure combines the following characterizations in to one measure:

EP: Freezer Early Removal

EH: Refrigerator Early Removal and Freezer Early Removal

LI: Refrigerator Early Removal and Freezer Early Removal

MF: Refrigerator Early Removal and Freezer Early Removal

Applicable markets

Efficient Products
Multi Family
Existing Homes
Low Income Single Family

Referenced Documents

- Refrigerator kW Calculations
- KEMA_RARP_report_to_SCE_040726
- FinalResidentialRetroEvaluationReport_11
- Refrig Freezer Retirement Analysis_2018
- Appliance Recycling Update no single door

Description

This is an early retirement measure for the removal of an existing inefficient secondary refrigerator or freezer from service either through a curbside pick up program or when a suitable unit is removed during a house visit. The program will target refrigerators with an age greater than 10 years, though data from units removed through the program suggests the average age of retired units is over 25 years. Savings are calculated for the estimated energy consumption during the assumed remaining life of the unit.

Baseline Efficiencies

The existing refrigerator baseline consumption is based upon data collected by Jaco from units retired in the last EVT program 2015.

High Efficiency

N/A

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh/Hours

Symbol Table

Electric Energy Savings

ΔkWh	= UEC × PartUse × HF

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

HF = Household Factor, to adjust savings based on the household type from which unit is removed.
= 84% for low income[2], 72% for multi family[3] , 1.0 for all others

Hours = Equivalent Full Load Hours
= 8477[1]

PartUse = Part use adjustment factor to account for average use of appliance through the year [4]

Unit Type	PartUse
Refrigerator	99.6%
Freezer	99.8%

UEC = Unit Energy Consumption of the retired unit[5]

Unit Type	UEC (kWh)
Refrigerator	746
Freezer	825

Load Shapes

4b Residential Refrigerator

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8%	33.0%	17.1%	19.1%	79.6%	100.0%

Net Savings Factors

Measures

RFRRERPS Refrigerator early retirement program, secondary

Tracks [Base Track]

6032EPEP [is base track] Efficient Products - Residential

Persistence
The persistence factor is assumed to be one.

Lifetimes
8 years[6]

Analysis period is the same as the lifetime.

Measure Cost
The cost of the administrative, pickup and recycling of the refrigerator is $110 based upon cost provided by Jaco during previous program.

O&M Cost Adjustments
There are no operation and maintenance cost adjustments for this measure.

Reference Tables
Prescriptive savings are provided below:

Unit Type	Reporting Category	Algorithm	kWh savings	kW savings
Refrigerator	Low Income	746 * 0.996 * 0.84	624	0.074
	Multi family	746 * 0.996 * 0.72	535	0.063
	All other (Efficient Products and Existing Homes)	746 * 0.996 * 1.0	743	0.088
Freezer	Low Income	825 * 0.998 * 0.84	692	0.082
	Multi family	825 * 0.998 * 0.72	593	0.070
	All other (Efficient Products and Existing Homes)	825 * 0.998 * 1.0	823	0.097

Footnotes
[1] Consistent with other Residential Refrigerator measures and based on the ratio of UEC to kW, calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. For the calculation see "Refrigerator kW Calculations.xls".

[2] Size Factor is calculated by comparing the average Low Income retrofitted energy savings per unit (592kwh for ENERGY STAR and 620 for CEE T2) to the average single family residential retrofitted energy savings (709kWh for ENERGY STAR and 737 for CEE T2) indicating a 84% savings factor.

[3] Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (726kWh) indicating a 72% savings factor.

[4] Based on analysis of Jaco data for program year 2015. Participants were asked how much the refrigerator was run through the year and the average result divded by 12 months.

[5] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired during the last year of the program 2015. To estimate the consumption of the retired units EVT applied results from this program data in a regression equation performed in a recent Cadmus Illinois evaluation (equation coefficients provided in a July 30 memo from Cadmus: "Appliance Recycling Update no single door"). See "Refrig Freezer Retirement Analysis_2018.xlsx".

[6] KEMA "Residential refrigerator recycling ninth year retention study", 2004, page 3-1.

Freezer Early Replacement

Measure Number:	R-RFG-FRER e
Portfolio:	EVT TRM Portfolio 2020-01
Status:	Active
Effective Date:	2020/1/1
End Date:	[None]
Program:	Low Income Single Family
End Use:	Refrigeration

Update Summary

Included deemed energy savings estimates for the low income single-family voucher program. As part of this revision, changed some verbiage for the measure description, baseline equipment, and reference notes. To account for the low income single-family voucher program and how the age of the freezer is no longer a restriction to participation, (meaning any age freezer is eligible for replacement as part of the program), created an additional input for kWh_Exist variable that is specifically for this program that is a weighted average of baseline unit electricity consumption based on the age of the freezer from data sourced from the VT SF Existing Homes On-Site Market Assessment Report.

Applicable Markets

Applicable Markets
Multifamily
Low Income Single Family
Existing Homes

Referenced Documents

- Refrigerator kW Calculations
- 2003 D&R Int. Freezer Fact Sheet
- 2020 VT Appliance Data_TRMCostAnalysis
- EVT_Freezer ER_Analysis_Mar 2020_2020

Description

An ENERGY STAR qualifying residential freezer is installed replacing an existing unit. Units must be pre-1993 in order to be eligible for early replacement. If age is unknown, the units can be metered to determine consumption. If metering indicates an annual consumption of ≥990 kWh or a savings of ≥565kWh, the measure is eligible. Eligibility can also be based upon a visual inspection, where the unit appears to be in poor condition such as leaking seals or warped doors. In this instance a reduced savings (based on 1993-2001 units) should be claimed.

However, for the low income single-family voucher program, the age and condition of the equipment does not preclude customers from participation, allowing for any eligible freezer, regardless of age or condition to be replaced. The baseline in this instance is a weighted average of freezers in Vermont single-family homes based on equipment age. After the first three years, which accounts for the remaining life of the replaced unit, the baseline shifts to a new freezer meeting the minimum federal efficiency standard for freezers effective September 15^{th}, 2014.

Program Type

Calculation Type: Early Replacement

Program Delivery / Implementation Type: Downstream and Free Product (Low Income Single-Family Voucher Program)

Baseline Efficiencies

Downstream: Baseline efficiency for the first three years is an existing pre-1993 freezer meeting the minimum federal standard effective in 1990 (except for units eligible via visual inspection only, where a 1993-2001 freezer is assumed based on federal standard effective in 1993). After that the baseline is a new refrigerator meeting the minimum federal efficiency standard effective September 15^{th}, 2014.

Low Income Single-Family Voucher Program: Baseline efficiency for the voucher program for the first three years is an existing freezer where the age and condition of the freezer is unknown. The baseline efficiency is a weighted average of freezers based on equipment age and meeting the minimum federal standards at the date of manufacturing.[1] After the first three years, which accounts for the remaining life of the replaced unit, the baseline shifts to a new freezer meeting the minimum federal efficiency standard for freezers effective September 15^{th}, 2014.

High Efficiency

The High Efficiency level is a freezer meeting ENERGY STAR specifications for efficiency established September 15, 2014 (at least 10% more.efficient than federal standard units).

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh/Hours
$\Delta kW_{\text{Pre-1993 units for remaining life of existing unit (3 years)}}$	= 512.4/8477 = **0.0604 kW**
$\Delta kW_{\text{Pre-1993 units for remaining measure life}}$	= 59.8/8477 = **0.0071 kW**
$\Delta kW_{\text{1993 - 2001 units for remaining life of existing unit (3 years)}}$	= 259.8/8477 = **0.0306 kW**
$\Delta kW_{\text{1993-2001 units for remaining measure life}}$	= 59.8/8477 = **0.0071 kW**
$\Delta kW_{\text{Voucher units for remaining life of existing units (3 years)}}$	= 274.5/8477 = **0.0324 kW**
$\Delta kW_{\text{Voucher unit for remaining measure life}}$	= 59.8/8477 = **0.0071 kW**

Symbol Table

Electric Energy Savings

ΔkWh	$= kWh_{EXIST} - kWh_{ESTAR}$ (for remaining life of existing unit (1st 6 years)) $= kWh_{base} - kWh_{ESTAR}$ (for remaining measure life)
$\Delta kWh_{\text{Pre-1993 units for remaining life of existing unit (1st 3 years)}}$	= 1010.3 - 497.9 = 512.4 kWh
$\Delta kWh_{\text{Pre-1993 units for remaining measure life}}$	= 497.9 - 438.1 = 59.8 kWh
$\Delta kWh_{\text{1993- 2001 units for remaining life of existing unit (1st 3 years)}}$	= 757.7 - 497.9 = 259.8 kWh
$\Delta kWh_{\text{1993-2001 for remaining measure life}}$	= 497.9 - 438.1 = 59.8 kWh
$\Delta kWh_{\text{Voucher units for remaining life of existing unit (1st 3 years)}}$	= 772.4 - 497.9 = 274.5 kWh
$\Delta kWh_{\text{Voucher units for remaining measure life}}$	= 497.9 - 438.1 = 59.8 kWh

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
Hours	=	Equivalent Full Load Hours = 8477[2]
kWh_{base}	=	Baseline kWh consumption per year = 497.9 kWh[3]
kWh_{ESTAR}	=	ENERGY STAR kWh consumption per year = 438.1 kWh[4]
kWh_{EXIST}	=	Assumed kWh consumption of existing unit being replaced Pre-1993 units = 1010.3 kWh[5] 1993-2001 units = 757.7 kWh[6] Vouncher units = 772.4 kWh[1]

Deemed Energy and Demand Savings

	ΔkWh Remaining Life of Existing Unit	ΔkWh Remaining Measure Life	ΔkW Remaining Life of Existing Unit	ΔkW Remaining Measure Life	Mid life Adjustment	ItemCode
Pre -1993	512.4	59.8	0.0604	0.0071	11.7%	LIFRZERP
1993-2001	259.8	59.8	0.0306	0.0071	23.0%	LIFRZERP1
Voucher (age unknown)	274.5	59.8	0.0324	0.0071	21.8%	EHFRZERVOU

Mid Life Savings Adjustment

For early replacement measures a mid life adjustmet of 59.8/512.4 = 11.7% will be applied after 3 years for pre-1993 units; 59.8/259.8 = 23.0% for 1993-2001 units; and 59.8/274.5 = 21.8% for voucher program units.

Load Shapes

4b Residential Refrigerator

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8%	33.0%	17.1%	19.1%	79.6%	100.0%

Net Savings Factors

Measures

RFRESFZR	Energy star freezer, early replacement

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6017PRES [is base track]	6017PRES
6020PRES [is base track]	6020PRES

Lifetimes

For early replacement measures, the remaining useful life of the existing unit is assumed to be 3 years. For market opportunity measures lifetime is assumed to be 16 Years.[7] Analysis period is the same as the lifetime.

Measure Cost

The full cost for an ENERGY STAR unit is $620. The cost of a baseline replacement freezer is $580.[8]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Footnotes

[1] Average equivalent 1990, 1993, 2001, and 2014 Federal Standard consumption for all units on ENERGY STAR qualified list, accessed 05/2019. See "EVT_Freezer ER_Analysis_Mar 2020_2020.xls". (The Code of Federal Regulations (10 CFR 430.32(a)) has appliance energy standards statutes for refrigerators and freezers that was used to create age categories, specific for the voucher program; (1) pre-1993; (2) 1993-2001; (3) 2001-2014; and the current federal standards which became effective on September 15, 2014, (4) post-2014.) In order to define a single baseline unit consumption for the voucher program in which age is not being collected and is unknown, the annual electricity use, based on age, was weighted, using residential market assessment data for the age of refrigerators in Vermont, sourced from; NMR, Vermont Single-Family Existing Homes On-Site Report, Draft", Dec 2017 (Section 8.3 Separate Freezer; Table 76 Separate Freezers Year of Manufacture).

[2] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

[3] Average equivalent current Federal Standard consumption value for all units on ENERGY STAR qualified list accessed 05/2019. See "EVT_Freezer ER_Analysis_Mar 2020_2020.xls".

[4] Average of units on ENERGY STAR qualified list accessed 05/2019. See "EVT_Freezer ER_Analysis_Mar 2020_2020.xls".

[5] Average equivalent 1990 Federal Standard consumption for all units on ENERGY STAR qualified list, accessed 05/2019. See "EVT_Freezer ER_Analysis_Mar 2020_2020.xls".

[6] Average equivalent 1993 Federal Standard consumption for all units on ENERGY STAR qualified list, accessed 05/2019. See "EVT_Freezer ER_Analysis_Mar 2020_2020.xls".

[7] Source: 2003 D&R Int. Freezer Fact Sheet

[8] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. This value has been inflated assuming 2% inflation to estimate costs in 2020. See 2020 VT Appliance Data_TRMCostAnalysis.xlsfor data.

Energy Efficient Refrigerators

Measure Number:	RS-RFG-EERFG n
Portfolio:	
Status:	Active
Effective Date:	2021/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	Refrigeration

Update Summary

Added non-energy GHG savings and a natural refrigerant refrigerator option.

Applicable Markets

- **Multifamily**
- **Efficient Products**
- **Low Income Single Family**
- **Residential New Construction**
- **Existing Homes**

Referenced Documents

- refrig_finalrule_tsd
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- VT SF Existing Homes Onsite Report - DRAFT 122117
- LBNL_savings-lifetime-persistence-brief
- LI and MF size factor
- Refrigerator Retrofit Savings_v2
- Refrigerator Savings 2019_v2
- ENERGY STAR v5 Refrigerator Product Specifications
- AHRI_8018_Final_Report
- ARB Refrigerant Data
- EPA Supermarket Report_PUBLIC_30Nov05
- CARB_HFC Inventory_TSD_20160411
- EVT PIP 124 Refrigerant Management FINAL
- EVT_Analysis_Refrigerator Savings_June 2021

Description

A refrigerator meeting either ENERGY STAR specifications or the higher efficiency specifications of a ENERGY STAR Most Efficient, or CEE Tier 3 rated refrigerator is installed instead of a new unit of baseline efficiency. The measure applies to market opportunity and early replacement programs.

This measure includes a natural refrigerant option (R-290 and R-600a) meeting ENERGY STAR specifications and listed on their Qualified Products List.

Program Type

Calculation: Time of Sale (Market Opportunity) and Early Replacement

Program Delivery / Implementation Type: Downstream and Free Product (Low Income Single-Family Voucher Program)

Baseline Efficiencies

Baseline Efficiencies – New

Baseline efficiency is a new refrigerator meeting the minimum federal efficiency standard for refrigerators effective September 15th, 2014.

Note a different baseline is provided for each efficient level. This is to account for the fact that the average capacity of the most efficient units is significantly lower than that of the standard ENERGY STAR.

For Shift Model approach the actual rated consumption of the baseline unit will be known and used.

Baseline Efficiencies – Retrofit

Baseline efficiency for the first six years is the existing refrigerator. To be eligible, units must either be older than 1993 or be pre-2001 and deemed to be in significantly poor condition via a visual inspection (pre-1993 or unit in poor condition). However, for the low income single-family voucher program, the age and condition of the equipment does not preclude customers from participation, allowing for any eligible refrigerator, regardless of age or condition to be replaced. The baseline in this instance is a weighted average of refrigerators in Vermont single-family homes based on equipment age. After the first six years the baseline is a new refrigerator meeting the minimum federal efficiency standard for refrigerators effective September 15th, 2014.

High Efficiency

The High Efficiency level is a refrigerator meeting Energy Star specifications for efficiency effective September 15th, 2014 (10% above federal standard)[1], a refrigerator meeting ENERGY STAR Most Efficient, or meeting CEE Tier 3 specifications (20% above federal standards).

For the ENERGY STAR Natural Refrigerant option, it is a refrigerator meeting ENERGY STAR specifications and listed on the ENERGY STAR qualified products list with a R-600a or R-290 refrigerant.

For Shift Model approach the actual rated consumption of the efficient unit will be known and used.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / Hours

Symbol Table

Non-Energy GHG Savings

ΔGHG	= Charge x ΔLeak x ΔGWP

Symbol Table

Electric Energy Savings

ΔkWh (Market Opportunity and Market Shift)	$= (kWh_{base} - kWh_{eff}) \times HF$
ΔkWh (Early Replacement - 1st three years)	$= (kWh_{baseOLD} - kWh_{eff}) \times HF$
ΔkWh (Early Replacement - Remaining Life)	$= (kWh_{base} - kWh_{eff}) \times HF$

Where:

ΔGHG	=	Gross customer annual non-energy GHG savings (lbs. CO2e)
ΔGWP	=	Difference in global warming potential between the baseline refrigerant and efficient refrigerant (lbs CO2e / lb refrigerant) = 1,295.5[2]

ΔkW	=	Gross customer connected load kW savings for the measure
ΔkWh (Early Replacement - 1st three years)	=	Gross customer annual kWh savings for Early Replacement, remaining life of existing unit (1st three years)
ΔkWh (Early Replacement - Remaining Life)	=	Gross customer annual kWh savings for Early Replacement, remaining measure life
ΔkWh (Market Opportunity and Market Shift)	=	Gross customer annual kWh savings for Market Opportunity and Market Shift approach.
ΔLeak	=	Percentage of total charge that leaks from the system on an annual basis = 2%[3]
Charge	=	Charge of the refrigeration system, in units of mass (lbs) = 0.342 lb[4]
HF	=	Household Factor, to adjust savings for larger ENERGY STAR units only based on the household type from which unit is removed. = 82% for low income[5], 60% for multi family[6], 1.0 for all others or if unknown
Hours	=	Equivalent Full Load Hours 8477
kWh_{base}	=	Annual kWh consumption of baseline models meeting Federal Standard. Note different value for each category since the average capacity of available product in each category varies[7]

Efficiency Level of Unit Installed	kWh_{base}
ENERGY STAR	693
ENERGY STAR Natural Refrigerant	552
ENERGY STAR Most Efficient	460
CEE Tier 3	455

For Shift Model Approach only kWh_{base} = Actual Rated kWh [8]

$kWh_{baseOLD}$	=	Assumed consumption of existing unit being replaced. Note different value for each category since the average capacity of available product in each category varies.

Efficiency Level of Unit Installed[9]	Pre-1993 or unit in poor condition	Age Unknown
ENERGY STAR	1454[10]	817[11]
ENERGY STAR Natural Refrigerant	1158	651
ENERGY STAR Most Efficient	965	542
CEE Tier 3	955	537

kWh_{eff}	=	Annual kWh consumption of efficient models. Note different value for each category since the average capacity of available product in each category varies[12].

Efficiency Level	kWh
ENERGY STAR	632
ENERGY STAR Natural Refrigerant	494
ENERGY STAR Most Efficient	409
CEE Tier 3	349

For Shift Model Approach only kWh_{eff} = Actual Rated kWh [13]

Mid Life Savings Adjustment

For early replacement measures the following table provides the appropriate midlife adjustment to be applied:

	Single Family		Low Income Family		Multi Family		
Efficiency Level of Unit Installed	ΔkWh Early Replacement, 1	ΔkWh remaining life of ER	ΔkWh Early Replacement, 1	ΔkWh remaining life of ER	ΔkWh Early Replacement, 1	ΔkWh remaining life of ER	Midlife Adjustment
ENERGY STAR	822	61	674	50	493	36	7.4%
ENERGY STAR Natural Refrigerant Refrigerator	664	58	664	58	664	58	8.7%
ENERGY STAR Most Efficient	556	51	556	51	556	51	9.1%
CEE Tier 3	606	107	606	107	606	107	17.6%

	Low Income Single-Family Voucher Program		
Efficiency Level of Unit Installed	ΔkWh Early Replacement, 1	ΔkWh remaining life of ER	Midlife Adjustment
ENERGY STAR	151	50	32.9%
ENERGY STAR Most Efficient	133	51	38.1%
CEE Tier 3	188	107	56.7%

Load Shapes

4b Residential Refrigerator

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8%	33.0%	17.1%	19.1%	79.6%	100.0%

Net Savings Factors

Measures

RFRESRRP	Energy star refrigerator
RFRESRER	Energy star refrigerator, early replacement
RFRESRT3	Tier 3 refrigerator
RFRESRT2	Tier 2 refrigerator
RFRT2RER	CEE Tier 2 Refrigerator, Early Replacement
RFRT3RER	CEE Tier 3 Refrigerator, Early Replacement
RFRESMSH	Market Shift ENERGY STAR Refrigerator

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6038VESH [is base track]	RNC VESH
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES

6013EPEP [6032EPEP]	Efficient Products - Commercial

Persistence

The persistence factor is assumed to be one.

Lifetimes

17 years[14]

For early replacement, the remaining useful life of the existing unit is assumed to be 3 years.

Analysis period is the same as the lifetime.

Measure Cost

The incremental cost to the ENERGY STAR level is $12, to ENERGY STAR Most Efficient level is $21, to ENERGY STAR Natural Refrigerant is $21, and to CEE Tier 3 is $64 [15].

For early replacement measures the full cost of a baseline unit is assumed to be $802.The full cost of the installed ENERGY STAR efficient unit is assumed to be $814 for ENERGY STAR, $823 for ENERGY STAR Most Efficient, $823 for ENERGY STAR Natural Refrigerant, and $866 for CEE Tier 3.

O&M Cost Adjustments

N/A

Prescriptive Savings Tables

For Market Opportunity, deemed savings are as follows:

Efficiency Level of Unit Installed	ΔkWh	ΔkW	Item Code
ENERGY STAR	61	0.0072	EPP-RFR-T1
ENERGY STAR Natural Refrigerant Refrigerator	58	0.0068	EPP-RFR-T1G
ENERGY STAR Most Efficient	51	0.0060	EPP-RFR-T2
CEE Tier 3	107	0.0126	EPP-RFR-T3

For Market Opportunity Multifamily, deemed savings for ENERGY STAR are as follows (other efficiency levels provided above):

Efficiency Level of Unit Installed	ΔkWh	ΔkW	Item Code
ENERGY STAR	37	0.0043	MFFRIGES

For Early Replacement, deemed ΔkW savings:

	Single Family			Low Income			Multi Family			Low Income Single-Family Voucher Prorgram		
Efficiency Level of Unit Installed	ΔkW 1st three years	ΔkW remaining life	Item Code	ΔkW 1st three years	ΔkW remaining life	Item Code	ΔkW 1st three years	ΔkW remaining life	Item Code	ΔkW 1st three years	ΔkW remaining life	Item Code
ENERGY STAR	0.0969	0.0072	EHFRIGERP	0.0795	0.0059	LIFRIGERP	0.0582	0.0043	MFFRIGERP	0.0178	0.0059	LIFRIGERPVOU
ENERGY STAR Natural Refrigerant Refrigerator	0.0783	0.0068	EHFRIGERPG	0.0783	0.0068	LIFRIGERPG	0.0783	0.0068	MFFRIGERPG	N/A	N/A	N/A
ENERGY STAR Most Efficient	0.0655	0.0060	EHFRIGERP1	0.0655	0.0060	LIFRIGERP1	0.0655	0.0060	MFFRIGERP1	0.0156	0.0060	LIFRIGERPVOU1
CEE Tier 3	0.0715	0.0126	EHFRIGERP2	0.0715	N/A	LIFRIGERP2	0.0715	0.0126	MFFRIGERP2	0.0222	0.0126	LIFRIGERPVOU2

Early Replacement deemed ΔkWh savings:

	Single Family			Low Income			Multi Family			Low Income Single-Family Voucher Program		
Efficiency Level of Unit Installed	ΔkWh 1st three years	ΔkWh remaining life	Item Code	ΔkWh 1st three years	ΔkWh remaining life	Item Code	ΔkWh 1st three years	ΔkWh remaining life	Item Code	ΔkWh 1st three years	ΔkWh remaining life	Item Code
ENERGY STAR	822	61	EHFRIGERP	674	50	LIFRIGERP	493	36	MFFRIGERP	151	50	LIFRIGERPVOU
ENERGY STAR Natural Refrigerant Refrigerator	664	58	EHFRIGERPG	664	58	LIFRIGERPG	664	58	MFFRIGERPG	N/A	N/A	N/A
ENERGY STAR Most Efficient	556	51	EHFRIGERP1	556	51	LIFRIGERP1	556	51	MFFRIGERP1	133	51	LIFRIGERPVOU1
CEE Tier 3	606	107	EHFRIGERP2	606	107	LIFRIGERP2	606	107	MFFRIGERP2	188	107	LIFRIGERPVOU2

Deemed Non-Energy GHG Savings

Item Code	GHG Savings (lbs of CO2e)
EPP-RFR-T1G	8.86122
EHFRIGERPG	8.86122
LIFRIGERPG	8.86122
MFFRIGERPG	8.86122

Footnotes

[1] ENERGY STAR Program Requirements Product Specifications for Residential Refrigerators and Freezers, version 5.0, effective September 9, 2014

[2] The 100-year time horizon glonal warming potential difference between baseline and efficient refrigerant. Units are in lbs of carbon dioxide equivalent per lb refrigerant. The global warming potential of baseline unit refrigerant assumes R-134a, which is considered the most common refrigerant seen in household refrigerators. The GWP100 value for R-134a is assumed to be 1,300 lbs CO2e / lb refrigerant, as described by "Program Implementation Plan (PIP) 124", Refrigerant Management, EVT, attached. Efficient unit refrigerant is assumed to be either R-290 (Propane) or R-600a (Isobutane), which have GWP100 values of 4 and 5 respectively, per the California Air Resource Board (CARB) Refrigerant Management Program, whose assumptions can be found in the attached file: "ARB Refrigerant Data.xlsx". The average of GWP100 values for the efficient scenario is 4.5 lbs CO2e / lb refrigerant and is assumed to derive the difference in refrigerant GWP100 values (1,300 - 4.5 = 1,295.5)

[3] For self-contained systems, reports from both EPA (U.S. EPA, "Revised Draft Analysis of U.S. Commercial Supermarket Refrigerantion Systems", November 2005) and California Air Resource Board (CARB, "California's High Global Warming Potential Gases Emission Inventory - Emission Inventory Methodology and Technical Support Document", April 2016), suggest an average 1% annual leakage rate which likely represents a mixture of slow leakage and catastrophic failures. For this equipment type, the end-of-life (EOL) emissions are likely of equal, or greater, importance to that of the operational leakage, but the magnitude of this issue is varied in the literature. Some sources claim EOL emissions are at 77% or greater ("AHRI Project 8018 Final Report, Review of Refrigerant Management Programs", Navigant, January 2016), while others downplay this factor. It is likely that EOL refrigerant recovery has improved in recent years with more attention on this topic. However, it is also clear that not all refrigerant is being properly reclaimed at EOL. Efficiency Vermont estimates a total annual leakage rate of 2%, based on the estimated 1% average annual leakage rate, plus another 1% to represent some portion of the refrigerant that is not properly recovered at end of life.

[4] The average refrigerant charge of a residential refrigerator is sourced from the California Air Resource Board (CARB) Refrigerant Management Program, whose assumptions can be found in the attached file: "ARB Refrigerant Data.xlsx".

[5] Size Factor is calculated by comparing the average Low Income retrofitted energy savings per unit (709.1kWh) to the average single family residential retrofitted energy savings (868.5kWh) indicating a 82% savings factor. See "LI and MF size Factor.xls".

[6] Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (869kWh) indicating a 60% savings factor. See "LI and MF size Factor.xls".

[7] The average consumption value for each Federal Standard equivalent to the ENERGY STAR and ENERGY STAR Most Efficient units purchased through the Efficiency Vermont program in 2017 and 2018. Since there was only one CEE Tier 3 unit purchased, the CEE Tier 3 assumption is based upon the average of the Federal Standard for CEE T3 qualified units from the ENERGY STAR Qualified Products List. See 'EVT_Analysis_Refrigerator Savings_June 2021.xlsx'; tab "Savings".

The average consumption value for the baseline unit for ENERGY STAR Natural Refrigerants, which meets the federal standard established on Setpember 15th, 2014, is sourced from the ENERGY STAR QPL which reports on the equvalent federal baseline, taking into account product class and capacity. For more detail, please see: "Natural Refrigerants_ENERGY STAR Certified Refrigerators_2021.xlsx". This file contains the ENERGY STAR

QPL as accessed on February 3, 2021.

[8] Note that the baseline model may be different in different locations as the highest selling low efficiency unit will be selected.

[9] The existing unit assumption for when a Most Efficient, Natural Refrigerator, or CEE Tier 3 is installed is adjusted downwards to account for the significantly lower capacity of the more efficient units. See 'EVT_Analysis_Refrigerator Savings_June 2021.xlsx'; tab "Savings".

[10] Based on custom data using model numbers collected by Efficiency Vermont in 2008-2009 before measure became prescriptive and when only pre 1993 units were eligible. See "Refrigerator Retrofit Savings_v2.xls". These values (based on rated efficiency) are inflated by 10% to account for degradation of performance based on a LBNL estimate in "Energy Savings Lifetimes and Persistence".

Note for a post-1993 unit which is deemed eligible for replacement via a visual inspection by a EVT program representative will be in particularly poor condition and is therefore assumed to have a similar consumption to a pre-1993 unit.

[11] Based on custom data using model numbers collected by Efficiency Vermont in 2008-2009 before measure became prescriptive. Leverages average annual electricity use of new refrigerators and freezers from the Association of Home Appliance Manufactures (AHAM), which captures the electricity use of refrigerators over time as federal appliance standards became active. The Code of Federal Regulations (10 CFR 430.32(a)) has appliance energy standards statutes for refrigerators and freezers that was used to create age categories for this measure; (1) pre-1993; (2) 1993-2001; (3) 2001-2014; and the current federal standards which became effective on September 15, 2014, (4) post-2014). The annual electricity use was then weighted, using residential market assessment data for the age of refrigerators in Vermont, sourced from; NMR, Vermont Single-Family Existing Homes On-Site Report, Draft", Dec 2017 (Section 8.2 Refrigerators; Table 73 Refrigerator Year of Manufacture). The unit electric consumption was further inflated (based on rated efficiency) by 10% to account for degredation of performance based on a LBNL estimate in "Energy Savings Lifetimes and Persistence". For more detail, please see: "Refrigerator Retrofit Savings_v2.xls".

[12] The average consumption value for each ENERGY STAR and ENERGY STAR Most Efficient unit purchased through the Efficiency Vermont program in 2017 and 2018. Since there was only one CEE Tier 3 unit purchased, the CEE Tier 3 assumption is based upon the average of the T3 qualified units from the ENERGY STAR Qualified Products List. See ''EVT_Analysis_Refrigerator Savings_Apr 2021.xlsx"; tab "Savings".

The average consumption value for ENERGY STAR Natural Refrigerants is sourced from the ENERGY STAR QPL as accessed on February 3, 2021. For more detail, please see: "Natural Refrigerants_ENERGY STAR Certified Refrigerators_2021.xlsx"

[13] Note that the efficient model may be different in different locations as a efficient model will be selected that is from the same manufacturer as the baseline model.

[14] Based on 2011 DOE Rulemaking Technical Support Document. See page 8-30 of 'refrig_finalrule_tsd.pdf'.

[15] Based on inflating to $2018 the $2009 costs provided in Tables 8.1.1 and 8.2.2 DOE 2011-08-26 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers and Freezers. See 'EVT_Analysis_Refrigerator Savings_June 2021.xlsx'; tab "Costs".

High Efficiency Evaporators

Measure Number: VIII-D-16 a
Portfolio: EVT TRM Portfolio 2019-07
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Commercial & Industrial
End Use: Refrigeration

Update Summary

New measure

Referenced Documents

- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Navigant, "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", 2013.
- Oak Ridge National Laboratory, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits", 2015.
- AESC Inc., "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators", 2016.
- Evaporator Fan Controls_NEEP_ICS4 Final June 23 2015.xlsx
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- Evaporator Motors Reference 2017_v4
- U.S. DOE Commercial Refrigeration Savings Potential_Navigant_2009
- Bohn Low Profile Unit Coolers Spec Sheet
- Intertek Memo_Heatcraft_Smart Defrost Kit Savings Validation_2007
- Manufacturer Savings Claims_MasterBlt_Master Controller_Savings Map
- EEV Savings and Benefits_Noro_July 2008
- Interlink Parts Smart Defrost Kit _ Energy Savings Calculator
- Refrigeration Analysis Tool v5f_TRM Test
- EVT_HE Evaporators_Analysis_May 2019_v5

Description

This measure characterizes the savings attributed to an upstream commercial refrigeration high efficiency evaporator unit. This initiative is designed to capitalize on market opportunities to drive the installation of efficient evaporator units instead of standard baseline options. This measure is applicable to evaporator units installed in walk-in cold storage applications, serving Low (0°F) and Medium (32°F) conditioned environments.

The high efficiency evaporator measure is structured under two distinct efficiency tiers, depending on the attributes incorporated into the unit. Tier 1 requisite attributes are programmable brushless permanent magnet (BLPM) or permanent magnet synchronous (Sync) motors for the evaporator fans and evaporator fan motor controls. The Tier 2 characterizations contains the elements of Tier 1 with the incrementalization of smart defrost controls and an electronic expansion valve (EEV). The collective effect of these features results in the refrigeration load requirements being met while using less power, as compared to a baseline unit. Energy and demand savings are appreciated for each tier through a measure by measure step incremental improvement approach.

Tier 1: Brushless permanent magnet motors (sometimes referred to as ECM, ICM, or brushless DC motors) and permanent magnet synchronous motors (sometimes referred to as synchronous, Sync, or Q-Sync motors) offer efficiency gains for evaporator fans over baseline options such as shaded pole (SP) or permanent split capacitor (PSC) motors. Evaporator fan motor controls reduce fan run time or speed depending on the required refrigeration load. Evaporator fans typically run continuously and the application of fan motor controls modulate the fan speed or run time with the refrigeration compressor to operate when the system is delivering a refrigeration load. Additionally, energy savings are realized through the reduced load on the refrigeration compressor caused by a reduction in excess heat given off by the evaporator fans when in operation. Energy savings are realized at the evaporator unit.

Tier 2: Evaporator coil smart defrost controls uses temperature and pressure sensors to monitor system processes and skip the electric defrost cycle if it is not needed. For an evaporator unit in a walk-in cold storage application, the defrost cycle operates periodically throughout the day. Smart defrost controls leverage statistical modeling to learn the operations and requirements of the system, reducing defrost cycles if unnecessary. Electronic expansion valves (EEV) offer efficiency gains over baseline thermostatic expansion valves. Expansion valves regulate the temperature and pressure of the refrigerant in the refrigeration cycle and manages the flow of fluid reaching the evaporator. Electronic expansion valves optimize refrigeration performance by improving refrigerant regulation precision, which can optimize overheating in the evaporator and improve overall compressor performance. Energy savings are based on an overall increase in the system's suction temperature, which result in a reduction in the suction pressure and a reduced load on the compressor.

Program Type

Market Opportunity: Time of Sale

Program Delivery / Implementation Type

Upstream

Baseline Efficiencies

A baseline unit is an evaporator with shaded pole (SP) or permanent-split capacitor (PSC) fan motors, no evaporator fan motor or smart defrost controls, and a thermostatic expansion valve.

Efficient Equipment

An efficient unit is a high efficiency evaporator with two tiers of measure attributes:

Tier 1: An evaporator unit with BLPM or Sync fan motors and fan motor controls.

Tier 2: An evaporator unit with Tier 1 attributes combined with evaporator coil smart defrost controls and an electronic expansion valve.

Algorithms

Electric Demand Savings

ΔkW_{Fans}	$= ((W_{Fan\ Out} \times (1 / \eta_{Base})) - (W_{Fan\ Out} \times (1 / \eta_{EE}))) \times N_{Fan} \times DC_{Evap} \times BF / 1000$
$\Delta kW_{Fan\ Controls}$	$= (W_{Fan\ Out} \times (1 / \eta_{EE}) / 1000) \times N_{Fan} \times LRF \times BF$
$\Delta kW_{Defrost\ Controls}$	$= kW_{DE} \times N_{Fan} \times SVG_{DE} \times BF$
ΔkW_{EEV}	$= \Sigma((Capacity / 1000) \times (DC_{Comp} \times SVG_{EEV}) / EER)$
$\Delta kW_{Tier\ 1}$	$= \Delta kW_{Fans} + \Delta kW_{Fan\ Controls}$
$\Delta kW_{Tier\ 2}$	$= \Delta kW_{Fans} + \Delta kW_{Fan\ Controls} + \Delta kW_{Defrost\ Controls} + \Delta kW_{EEV}$

Symbol Table

Water Savings

N/A

Electric Energy Savings

ΔkWh_{Fans}	$= \Delta kW_{Fans} \times 8760$
$\Delta kWh_{Fan\ Controls}$	$= \Delta kW_{Fan\ Controls} \times 8760$
$\Delta kWh_{Defrost\ Controls}$	$= \Delta kW_{Defrost\ Controls} \times FLH$
ΔkWh_{EEV}	$= \Delta kW_{EEV} \times Hours$

$\Delta kWh_{Tier\ 1}$	$= \Delta kWh_{Fans} + \Delta kWh_{Fan\ Controls}$
$\Delta kWh_{Tier\ 2}$	$= \Delta kWh_{Fans} + \Delta kWh_{Fan\ Controls} + \Delta kWh_{Defrost\ Controls} + \Delta kWh_{EEV}$

Symbol Table

Fossil Fuel Savings
N/A

Where:

$\Delta kW_{Defrost\ Controls}$	=	Gross connected load kW savings associated with smart defrost controls.
ΔkW_{EEV}	=	Gross connected load kW savings associated with the electonic expansion valve.
$\Delta kW_{Fan\ Controls}$	=	Gross connected load kW savings associated with evaporator fan motor controls.
ΔkW_{Fans}	=	Gross connected load kW savings associated with high efficiency fan motors.
$\Delta kW_{Tier\ 1}$	=	Gross connected load kW savings associated with Tier 1
$\Delta kW_{Tier\ 2}$	=	Gross connected load kW savings associated with Tier 2
$\Delta kWh_{Defrost\ Controls}$	=	Gross annual kWh energy savings associated with smart defrost controls.
ΔkWh_{EEV}	=	Gross annual kWh energy savings associated with the electronic expansion valve.
$\Delta kWh_{Fan\ Controls}$	=	Gross annual kWh energy savings associated with evaporator fan motor controls.
ΔkWh_{Fans}	=	Gross annual kWh energy savings associated with high efficiency fan motors.
$\Delta kWh_{Tier\ 1}$	=	Gross annual kWh energy savings associated with Tier 1
$\Delta kWh_{Tier\ 2}$	=	Gross annual kWh energy savings associated with Tier 2
η_{Base}	=	Efficiency of the baseline fan motor = 0.31[1]
η_{EE}	=	Efficiency of the high efficiency fan motor = 0.66[2]
8760	=	Annual operating hours per year of the evaporator fans
BF	=	Bonus factor for reduced cooling load from eliminating excess heat generated by the evaporator fans inside the walk-in cold storage area. = 1.4[3]
Capacity	=	Operating capacity of the compressor in Btu/h = 39,600 Btu/h[4]
DC_{Comp}	=	Duty cycle of the compressor = 45%[5]
DC_{Evap}	=	Duty cycle of the evaporator fan = 97.8%[6]
EER	=	Energy Efficiency Ratio of the compressor[7]
FLH	=	Average full load defrost hours = 487 hours[14]
Hours	=	Total summation of bin operating hours for the compressor = 8,417 hours[15]
kW_{DE}	=	Connected load (kW) of the defrost element per evaporator fan = 0.9 kW[8]
LRF	=	Load Reduction Factor for the evaporator fan motor controlled units = 31.3%[9]
N_{Fan}	=	Number of evaporator fans = see reference table for deemed assumptions[10]
SVG_{DE}	=	Energy saviings factor for the smart defrost controls; % of defrost cycles saved by controls = 30%[11]
SVG_{EEV}	=	Energy savings factor for the electronic expansion valve; % of compressor cycle saved by EEV =4.5%[12]
$W_{Fan\ Out}$	=	Rated wattage output of the evaporator fan motor = 42 watts[13]

Mid-Life Savings Adjustment
N/A

Load Shapes
132a High Efficiency Evaporator - Tier 1
133a High Efficiency Evaporator - Tier 2

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
132	High Efficiency Evaporator - Tier 1	Active	30.7%	36.0%	15.5%	17.8%	96.3%	96.3%
133	High Efficiency Evaporator - Tier 2	Active	31.3%	35.1%	15.9%	17.7%	30.3%	31.2%

Net Savings Factors

Measures

RFRHEET1	High efficiency evaporator, tier 1
RFRHEET2	High efficiency evaporator, tier 2

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	RFRHEET1	1.00	1.00

Upstream - Commercial	6013UPST	RFRHEET2	1.00	1.00

Lifetimes

The measure life is assumed to be 15 years[16]

Measure Cost

Measures	Unit	Incremental Cost
Evaporator Fan Motors	per fan	$143[17]
Evaporator Fan Motor Controls	per evaporator	$520[18]
Smart Defrost Controls	per evaporator	$500[19]
Electronic Expansion Valve (EEV)	per evaporator	$40[20]

O&M Cost Adjustments

N/A

Reference Tables

Deemed Energy and Demand Savings

Deemed Measure	Tier 1			Tier 2		
	ΔkW	ΔkWh	Incremental Cost	ΔkW	ΔkWh	Incremental Cost
1 Fan Evaporator	0.1263	1,106	$663	0.5802	1,929	$1,203
2 Fan Evaporator	0.2526	2,212	$806	1.0845	3,219	$1,346
3 Fan Evaporator	0.3789	3,318	$949	1.5888	4,509	$1,489
4 Fan Evaporator	0.5052	4,424	$1,092	2.0931	5,799	$1,632
5 Fan Evaporator	0.6315	5,530	$1,235	2.5974	7,089	$1,775
6 Fan Evaporator	0.7578	6,636	$1,378	3.1017	8,379	$1,918

Reference Table: Item Codes

Deemed Measure	Item Code
1 Fan Evaporator, Tier 1	HEEVAP1F1T
2 Fan Evaporator, Tier 1	HEEVAP2F1T
3 Fan Evaporator, Tier 1	HEEVAP3F1T
4 Fan Evaporator, Tier 1	HEEVAP4F1T
5 Fan Evaporator, Tier 1	HEEVAP5F1T
6 Fan Evaporator, Tier 1	HEEVAP6F1T
1 Fan Evaporator, Tier 2	HEEVAP1F2T
2 Fan Evaporator, Tier 2	HEEVAP2F2T
3 Fan Evaporator, Tier 2	HEEVAP3F2T
4 Fan Evaporator, Tier 2	HEEVAP4F2T
5 Fan Evaporator, Tier 2	HEEVAP5F2T
6 Fan Evaporator, Tier 2	HEEVAP6F2T

Footnotes

[1] Efficiencies for the baseline shaded pole (SP) and permanent split capacitor (PSC) fan motors were determined using an average of baseline motor efficiencies, as sourced from the; "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", Navigant, 2013 (page 5; table 2.1) and "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits", Oak Ridge National Laboratory, 2015 (page 1; section 1). The baseline fan motor efficiency of 31% represents a weighted average efficiency of SP and PSC fan motors, which was derived from past participation results for the EVT Evaporator Fan Motor measure for replaced baseline motors in walk-in coolers. For more detail on this weighting, please see "EVT_HE Evaporators_Analysis_May 2019_v4.xlsx".

[2] Efficiency of a BLPM evaporator fan motor, as sourced from "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits", Oak Ridge National Laboratory, 2015 (page 1; section 1)

[3] The average bonus factor is derived from the Northeast Energy Efficiency Partnership (NEEP) Refrigeration Loadshape Report - "Commercial Refrigeration Loadshape Project Final Report", Cadmus, Regional Evaluation, Measurement, and Verification Forum, 2015 (page 78; figure 54). The 1.4 bonus factor represents a weighted average of low, medium, and high temperature refrigeration types for walk-in coolers/freezers.

[4] Average compressor capacity, as sourced from "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration", U.S. DOE, Navigant, 2009 (page 69, results based on a 5 hp semi-hermetic compressor for the walk-in cooler and a 1.5 hp semi-hermetic compressor for the freezer. Weighting for walk-in type was based on past EVT participation for Evaporator Fan Motors.)

[5] The average compressor duty cycle is 45%, based on a compressor full load operation of 3,910 hours. This value is sourced from EVT's custom refrigeration analysis tool, "Refrigeration Analysis Tool_v5f_TRM Test.xlsm".

[6] An evaporator fan runs on average 8,567 hours per year; 97.8% of the full 8,760 hours in a year. This value is sourced from the Northeast Energy Efficiency Partnership (NEEP) Refrigeration Loadshape Report - "Commercial Refrigeration Loadshape Project Final Report", Cadmus, Regional Evaluation, Measurement, and Verification Forum, 2015 (page 67; table 34).

[7] The compressor EER varies depending on the outdoor air and condensing set temperatures. For the purposes of this characterization, the energy savings associated with the EEV were summed across different temperature bins. The average compressor EER of 10.6 (at a typical condensing set point of 90°F and a saturated suction temperature of 20°F) is sourced from the "Energy Savings Potential and R&D Opportunities for Commercial Refrigeration", U.S. DOE, Navigant, 2009 (page 69, results based on a 5 hp semi-hermetic compressor for the walk-in cooler and a 1.5 hp semi-hermetic compressor for the freezer. Weighting for walk-in type was based on past EVT participation for Evaporator Fan Motors). The EER multipliers at the varying bins, which were used to determine the reduced effects of the compressor at higher outdoor air and condensing temperatures, were taken as a straight average from the EVT's custom refrigeration analysis tool, "Refrigeration Analysis Tool_v5f_TRM Test.xlsm".

[8] The electric defrost element kW is proportional to the number of evaporator fans blowing over the evaporator coil. The average wattage of the defrost element per fan is based on manufacturer specifications for evaporators from Bohn and Larkin (see: "Bohn Low Profile Unit Coolers Spec Sheet.pdf").

[9] The load reduction factor (LRF) is sourced from Northeast Energy Efficiency Partnership (NEEP) Refrigeration Loadshape Report - "Commercial Refrigeration Loadshape Project Final Report", Cadmus, Regional Evaluation, Measurement, and Verification Forum, 2015 (page 67; table 34). The LRF is the difference in effective runtime of uncontrolled motors and the effective runtime of all control styles for evaporator fan motor controls.

[10] Energy savings are based on the number of fans per evaporator unit. Reference tables are provided to detail deemed savings depending on the number of evaporator fans. For prescriptive implementation purposes, the number of fans will be collected for each rebated unit.

[11] Evaporator coil smart defrost controls typically claim between 30 and 40% in savings. For added reference, 43.6% in energy savings was verified by third-party testing conducted by Intertek Testing Services on Heatcraft InterLink Smart Defrost Kit (see "Intertek Memo_Heatcraft_Smart Defrost Kit Savings Validation_2007.pdf"). Additionally, a manufacturer of smart defrost controls, MasterBilt Refrigeration Solutions Demand Defrost, claims 21% in savings for northeast applications (see "Manufacturer Savings Claim_MasterBilt_Master controller_Savings Map.pdf"). For purposes of this measure characterization, an average energy savings factor assumption of 30% was used. This value is also corroborated by custom assumptions used in EVT's analysis for refrigeration projects, "Refrigeration Analysis Tool_v5f_TRM Test.xlsm".

[12] Compressor consumption reduction for the EEV measure is based on an overall increase in the suction temperature, which results in a reduction in the suction pressure. The EVT Refrigeration Analysis tool ("Refrigeration Analysis Tool_v5f.xlsm") used for custom refrigeration projects, assumes a 1.5% reduction in compressor consumption per degree increase in the suction temperature; a factor based on engineering judgement. For practical purposes for this measure, a 3°F change in the suction temperature is assumed.

[13] The evaporator fan motor wattage is based on motor type efficiencies and output ratings as calculated from power consumption values for baseline walk-in motors from the following analysis file "Evaporator Motors Reference 2017_v4.xlsx", "Savings Table" tab. The original source material is the Northeast Energy Efficiency Partnership (NEEP) Refrigeration Loadshape Report - "Commercial Refrigeration Loadshape Project Final Report", Cadmus, Regional Evaluation, Measurement, and Verification Forum, 2015 (page 87; section 5.1.4)

[14] The average annual full load hours of the defrost cycle is based on 4 defrost cycles per day, lasting in duration for 20 minutes per cycle. This value is sourced from EVT's custom refrigeration analysis tool, "Refrigeration Analysis Tool_v5f_TRM Test.xlsm".

[15] The compressor operating hours is a based on a weighted average of walk-in cold storage applications and sites utilizing economizers. If a site leverages a refrigeration economizer, the compressor will not operate at outdoor air temperatures 4°F below the cold storage set temperatures. The weighting for sites with economizers is sourced from the "2016 Vermont Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 109). The weighting for the cold storage applications and associated average refrigeration set temperature is sourced from "Energy

Savings Potential and R&D Opportunities for Commercial Refrigeration", U.S. DOE, Navigant, 2009 (page 68). For more information on how the compressor operating hours were binned across the different outdoor air temperatures, please see "EVT_HE Evaporators_Analysis_May 2019_v4.xlsx".

[16] The 15 year measure life for evaporator fan motors is sourced from DEER 2014 effective useful life (EUL) estimates; California DEER 2014 Effective Useful Life Table Update, DEER2014-EUL-table-update_2014-02-05.xlsx. The 15 year measure life for evaporator fan motor controls is sourced from the EVT TRM measure characterization 'Evaporator Fan Motor Control'. The 15 year measure life for smart defrost controls is a conservative estimate based on an anecdotal conversaion with Heatcraft, a manufacturer of refrigeration equipment. Heatcraft estimated the measure life based on the components expected life where the only moving part is a relay which has a cycle life that is well over 15 years based on the frequency of the relay operation. The 15 year measure life for the EEV is sourced from a case study, "Energy savings and economic benefits of using electronic expansion valves in supermarket display cabinets", R.Lazzarin, D. Nardotto, and M. Noro, July 2008. Due to all component attributes associated with the high efficiency evaporator unit having a 15 year measure life, it was deemed appropriate to use this for each tier.

[17] Incremental costs for evaporator fan motors are determined from manufacturer quotes and listings for walk-in application. See reference files from the "Evaporator Motors Reference 2017_v4.xlsx" and "Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators", 2016 (page 26).

[18] Evaporator fan control unit cost of $520 is referenced from the NEEP Incremental Cost Study Part 4; spreadsheet as listed for the New England region on a per controller cost basis. See reference "Evaporator Fan Controls_NEEP_ICS4 Final June 23 2015.xlsx", "Summary of Results" tab.

[19] The evaporator coil smart defrost control is based on a typical Smart Defrost Kit cost of $400-$600 per system, as by a Heatcraft Interlink Parts Smart Defrost calculator (see "Interlink Parts Smart Defrost Kit _ Energy Savings Calculator.html"). The MasterBilt Master Controller and Beacon II systems are more complex control and data logging systems that do more than just defrost, and are therefore more costly. This measure characterization and the measure cost is only for the defrost control portion of the systems.This value is also used for custom project refrigeration costs, as sourced from the EVT Refrigeration Analysis Tool ("Refrigeration Analysis Tool_v5f_TRM Test.xlsm").

[20] Results of a recent training attended by Sheryl Graves on new High Efficiency Evaporators

Insulation and Airsealing

Measure Number: VII-K-2 a
Portfolio:
Status: Active
Effective Date: 2019/1/1
End Date: 2020/12/31
Program: Existing Homes
End Use: Thermal Shell

Update Summary

This is a new Efficiency Vermont offering and version one of the characterization.

Referenced Documents

- NEST VEIC Data Share 9Jun2017
- VT SF Existing Homes Onsite Report - DRAFT 122117
- DIY Support Workbook FINAL_new RR

Description

This characterization is in support of Efficiency Vermont's Existing Homes Insulation and Airsealing Program. Participants can elect to weatherize (airseal and insulate) either their flat, open attic OR their basement/crawlspace rim joists and walls. With the exception of selecting treatment area, site-specific heating systems and fuel types, savings for this measure are fully deemed values. Although this characerization is broken out by airsealing and insulation savings components, the final savings claim for the appropriate treatment area will be the sum of these two components. This is a retrofit measure, savings energy by increasing the thermal resistance of building assemblies and reducing air infiltration that would subsequently need to be heated by the heating system(s). The expectation is that the work will be completed by a qualified professional.

Additional program materials are linked in the Referenced Documents section and include the program rebate form and quality standards manual.

Program Type

Retrofit

Baseline Efficiencies

Baseline existing home attic and basement conditions are in large part defined by the information and data published in the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Baseline is therefore loosely defined as the typical, single-family existing home attic or basement that falls within EVT market territory. Descriptions, footnotes and references in the remaining characterization content clearly specify and describe the baseline treatment area characteristics.

Efficient Equipment

The efficient condition upgrades the insulation properties of the attic structural assembly to an overall weighted value of R-49 or the basement structural assembly to R-15. Additionally, comprehensive air sealing must have occurred, preferably through the application of polyurethane foam.

Algorithms

Electric Demand Savings

Demand savings are exclusive to the heating season and the winter peak demand period. The total electric savings for each source (e.g., heat pump) resulting from insulating and airsealing are divided by the expected full load heating hours to establish the demand reduction. The loadhshape is subsequently used in conjunction with this value to establish winter peak demand savings.

$$kW_{save} = kWh_{source} / EFLH_{eheat}$$

Symbol Table

Energy Savings: Airsealing

$$kWh_{save} = \%_{Load} \times \beta_{CFM50} \times \psi \times SF_n \times HDH_n \times 60 \times c_p \times \rho / (\eta_{source} \times N_{heat} \times \omega)$$

$$MMBtu_{save} = \%_{Load} \times \beta_{CFM50} \times \psi \times SF_n \times HDH_n \times 60 \times c_p \times \rho / (\eta_{source} \times N_{heat} \times \omega)$$

Symbol Table

Energy Savings: Insulation

This characterization limits the savings claim to the primary heating system only, although it is common for homes to have multiple heating sources. Both insulation and airsealing savings components are claimed and savings are limited to space heating savings. The savings calculations must be performed for the primary heating source, i.e., the system that contributes the largest proportion of heating load on a annual basis. An example at the end of this section illustrates how this characterization is used to claim savings.

$$kWh_{save} = \%_{Load} \times (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi / (\eta_{source} \times \omega)$$

$$MMBtu_{save} = \%_{Load} \times (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi / (\eta_{source} \times \omega)$$

Where:

$\%_{Load}$ = Portion of annual heating load supplied by the primary heating source.[2]

= 92.0%

β_{CFM50} = Infiltration improvement factor (CFM_{50}/ft^2)[3]

= 0.86878 (CFM_{50}/ft^2)

η_{source} = Operating efficiency of the heating source[4], dependent of fuel and system type:

System/ Fuel Type		Efficiency
Boiler	Oil	0.85
	Nat. Gas	0.873
	Propane	0.874
Furnace	Oil	0.814
	Nat. Gas	0.921
	Propane	0.90
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Catalytic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Gas/Propane stove	0.65
	Heat Pump	2.93
	Electric Resistance	1.00

ω = Conversion factor from Btu to MMBtu or kWh, as appropriate

= 1,000,000 (Btu/MMBtu) or 3,412.14 (Btu/kWh)

ψ	=	Adjustment factor to bring savings estimates given by this simplified algorithm to evaluation bill anaylsis results.[5] = 0.55 (dimensionless)
ρ	=	Density of air at prevalent conditions during the heating season (lb/ft^3) = 0.0749 (lb/ft^3)
60	=	Converts volumitric air flow per minute to hour = 60 (minutes/hour)
c_p	=	Specific heat of air at prevalent conditions during the heating season (Btu/lb F) = 0.24 (Btu/lb F)
$EFLH_{eheat}$	=	Effective Full Load Hours for electric heating source (hours) = 1,354.8 (hours)[1]
HDH_n	=	Heating Degree Hours[6], dependent on space being treated (F hr): = 127,691.3 (F hr) for flat, open attic OR 99,194.6 (F hr) for basement/crawlspace rim joists and walls
kW_{save}	=	Electric demand savings (kW)
kWh_{source}	=	Total electric energy savings from the primary, secondary, or tertiary source for insulation and airsealing improvements, as calculated in the **Energy Savings: Insulation** and **Energy Savings: Airsealing** sections (kWh)
kWh_{save}	=	Annual elecric energy savings (kWh)
$MMBtu_{save}$	=	Annual fuel savings (MMBtu)
N_{heat}	=	Conversion factor from volumetric air flow at 50 Pascal pressure to natural conditions[7] = 20 (dimensionless)
R_{post}	=	Thermal resistance of the improved (post-treatment) assemblies separating conditioned space to the ambient environment[9], dependent on space being treated (hr F ft^2/Btu): = 49.0 (hr F ft^2/Btu) for flat, open attic OR 22.4 (hr F ft^2/Btu) for basement/crawlspace rim joists and walls
R_{pre}	=	Thermal resistance of the existing (pre-treatment) assemblies separating conditioned space to the ambient environment[10], dependent on space being treated (hr F ft^2/Btu): = 29.0 (hr F ft^2/Btu) for flat, open attic OR 15.2 (hr F ft^2/Btu) for basement/crawlspace rim joists and walls
SF_n	=	Area of treatment with improved insulation and airsealing properties[8] = 852.87 (ft^2) for flat, open attic OR 967.59 (ft^2) for basement/crawlspace rim joists and walls

The following table summarizes the savings outcomes for each treatment area, treatment activity, heating system type, and fuel type. To exemplify how savings shall be claimed, let's assume a project has weatherized an open attic. The site has a primary natural gas furnace.

Natural gas savings: savings from insulating are established as 0.842 MMBtu and savings from airsealing are established as 2.807 MMBtu for total natural gas savings of 3.649 MMBtu

Summarized Savings Outcomes

				Flat, Open Attic		Basement/Crawlspace Rim Joists and Walls	
System/Fuel Type		Treatment	Savings Units	Primary Heat Souce, 92% heating load	Itemcode	Primary Heat Souce, 92% heating load	Itemcode
Boiler	Oil	Insulation		0.912		1.210	
		Airsealing		3.041		2.680	
		Total		3.954	PRO-A-BOIL-OIL	3.891	PRO-B-BOIL-OIL
	Nat. Gas	Insulation		0.888		1.178	
		Airsealing		2.961		2.610	
		Total		3.850	PRO-A-BOIL-NGAS	3.788	PRO-B-BOIL-NGAS
	Propane	Insulation		0.887		1.177	
		Airsealing		2.958		2.607	
		Total		3.845	PRO-A-BOIL-PROP	3.784	PRO-B-BOIL-PROP
Furnace	Oil	Insulation		0.953		1.264	
		Airsealing		3.176		2.799	
		Total		4.129	PRO-A-FURN-OIL	4.063	PRO-B-FURN-OIL
	Nat. Gas	Insulation		0.842		1.117	
		Airsealing		2.807		2.474	
		Total		3.649	PRO-A-FURN-NGAS	3.591	PRO-B-FURN-NGAS
	Propane	Insulation		0.862		1.143	
		Airsealing		2.872		2.532	
		Total		3.734	PRO-A-FURN-PROP	3.674	PRO-B-FURN-PROP
Other	Pellet stove	Insulation		1.108		1.469	
		Airsealing		3.693		3.255	
		Total		4.801	PRO-A-PLLT-WOOD	4.724	PRO-B-PLLT-WOOD
	Newer EPA woodstove	Insulation	MMBtu	1.293		1.714	
		Airsealing		4.309		3.797	
		Total		5.601	PRO-A-EPAW-WOOD	5.512	PRO-B-EPAW-WOOD
	Cataylitic woodstove	Insulation		1.551		2.057	
		Airsealing		5.170		4.557	
		Total		6.722	PRO-A-CATW-WOOD	6.614	PRO-B-CATW-WOOD
	Non-catalytic woodstove	Insulation		1.939		2.571	
		Airsealing		6.463		5.696	
		Total		8.402	PRO-A-NCAT-WOOD	8.267	PRO-B-NCAT-WOOD
	Outdoor wood boiler	Insulation		3.102		4.114	
		Airsealing		10.341		9.114	
		Total		13.443	PRO-A-ODWB-WOOD	13.228	PRO-B-ODWB-WOOD
	Open hearth fireplace	Insulation		7.756		10.285	
		Airsealing		25.852		22.784	
		Total		33.608	PRO-A-OHFP-WOOD	33.069	PRO-B-OHFP-WOOD
	Gas stove	Insulation		1.193		1.582	
		Airsealing		3.977		3.505	
		Total		5.170	PRO-A-STVE-NGAS	5.088	PRO-B-STVE-NGAS
	Gas stove	Insulation		1.193		1.582	
		Airsealing		3.977		3.505	
		Total		5.170	PRO-A-STVE-PROP	5.088	PRO-B-STVE-PROP
	Heat Pump	Insulation		77.6 (0.05725)		102.9 (0.07592)	
		Airsealing		258.5 (0.19082)		227.8 (0.16817)	
					PRO-A-HPMP-		PRO-B-HPMP-

		Total	kWh (kW)	336.1 (0.24807)	PRO-A-HPMP-ELEC	330.7 (0.24409)	PRO-B-HPMP-ELEC
	Electric Resistance	Insulation		227.3 (0.16778)		301.4 (0.22249)	
		Airsealing		757.7 (0.55924)		667.7 (0.49287)	
		Total		985 (0.72702)	PRO-A-ERES-ELEC	969.2 (0.71536)	PRO-B-ERES-ELEC

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%

Net Savings Factors

Measures

TSHNAIRS	Insulate and airseal

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Lifetimes

Lifetimes for both airsealing and insulating components are 25 years.[11]

Measure Cost

Total measure costs are comprised of the cost of airsealing and insulating the treatment area[12]:

Space	Total Cost - Insulation & Airsealing
Flat, Open Attic	$4,000.00
Basement/Crawlspace Rim Joists and Walls	$5,000.00

Footnotes

[1] $EFLH_{sheat}$ is taken to be the established full load hours for a heat pump under the premise that the majority of any eletric heat sources are likely to be heat pumps. Further, as this value is higher than the default EFLH for the loadshape applicable to this measure, the demand savings err on the conservative side. This value is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. See TRM measure Variable Speed Mini-Split Heat Pumps for additional background and reference documents. The analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_12_2017.xlsx.

[2] Based on analysis of the U.S. Energy Information Administration's Residential Energy Consumption Survey (RECS) 2009 dataset. Homes from the New England Census Division (CT, MA, ME, NH, RI, VT) were included in the analysis. Due to VEIC data systems limitations, only primary heating source savings are quantified and claimed. Savings for the remaining 8% of annual heating load is forgone in exchange for implementation efficiency. For access to the raw dataset and anlaysis, see the "RECS2009" worksheet in the DIY Support Workbook FINAL_newRR.

[3] Derived from dataset of ~4,400 past EVT home performance projects. Projects used blower door testing to establish improvement in airsealing performance. Total airsealed area divided by the change in volumetric flow rate blower door reading established the improvement factor for each project. The median value of the entire dataset was chosen to represent the improvement factor for this characterization to limit the impact of outliers. Complete dataset and analysis can be seen on the "Airsealing Improvement Factor" worksheet in the DIY Support Workbook FINAL_newRR.

[4] Boiler and furnace efficiencies are the median values reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 in Tables 46 and 47. Heat pump efficiency conservatively taken to be the minimum qualifying efficiency requirement for EVT's programs, HSPF = 10.0, converted to COP by dividing by 3.41214. All other efficiency values based on professional judgement.

[5] This adjustment factor mirrors that which is applied to HERO-based HPwES projects. Based on the 2018 program impact evaluation and subsequent outcomes of EM&V/DPS negotiations, the 0.55 adjustment factor is intended to better align the savings estimated by HERO algorithms to those established by evaluation. Since the algorithms used by this characterization closely align with HERO, the same adjustment factor is adopted.

[6] Heating Degree Hours for attic assumes a base temperature of 58 degrees F and uses Climate Normals data for Burlington Internation Airport. A recent Nest study by EVT revealed that a base temperature of 58 degrees is appropriate to capture the heating tendencies of a typical Vermont home. See referenced document "NEST VEIC Data Share 9Jun2017." In an attempt to make a conservative estimate of heating degree hours, it was assumed that only days within a defined heating season would be included in the total, assuming that homeowners would disable or set back heating systems in the off season. The heating season was defined as the time period where temperatures "consistently" fall below 58 degrees. Based on visual inspection of TMY3 data, this period was established as September 19th to May 6th. Heating Degree Hours for basement assumes a blend of conditioned and unconditioned space as reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Unconditioned space HDH assumes a base temperature of 48 degrees F based on the premise that unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool. See worksheets "Foundation Blend" and "HDH - Climate Normals" in the DIY Support Workbook FINAL_newRR for a complete derivation.

[7] A legacy negotiated value carried over from a historic EVT Home Performance With Energy Star program performance evaluation finding intended to bring savings predicted by this algorithm in line with evaluated impacts.

[8] The average area for open attics is derived from a dataset of ~4,400 past EVT home performance projects. See worksheets "Additional Assumptions" and "Airsealing Improvement Factor" for a complete derivation. Basement treatment area (wall area) uses median reported floor areas in the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 (Table 12) as a basis and assumes completely square areas, eight foot wall heights for full basements and four foot wall heights for crawlspaces. Final value is a weighted, composite number based on foundation type and prevalence in the EVT market territory. For a full derivation, see the worksheet "Foundation Blend" in the DIY Support Workbook FINAL_newRR.

[9] Based on program requirements, which align with Vermont RBES. The R-value for basements appears higher than what the program and RBES requires (R-15) due to the fact that the thermal resistance properties of soil have been accounted for in basements that are below grade. The final weighted number is a composite value based on statistics of homes with below, mixed and no basement (crawlspace) that have been sourced from the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. For a full derivation, see the worksheet "Foundation Blend" in the DIY Support Workbook FINAL_newRR.

[10] Baseline R-values sourced from the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Median (more conservative) value assumed for attics (Table 24, Page 26) and average values assumed for basements (Table 32, Page 32 & Page 33) due to the fact that median is not specified for above grade basement walls. The final value for basements is a weighted, composite value based on statistics of homes with below, mixed and no basement (crawlspace). Additionally, it accounts for the thermal resistance properties of soil. For a full derivation, see the worksheet "Foundation Blend" in the DIY Support Workbook FINAL_newRR.

[11] Consistent with EVT TRM measure "Comprehensive Shell Measure Savings"

[12] Costs based on EVT Engineering estimates, to be refined with actual program cost data as it becomes available and statistically significant.

HPwES 2.0 Airsealing

Measure Number: VII-K-2 e
Portfolio:
Status: Active
Effective Date: 2020/1/1
End Date: [None]
Program: Existing Homes
End Use: Thermal Shell

Update Summary

This is a new Efficiency Vermont offering for the Home Performance with Energy Star program and version one of the characterization.

Referenced Documents

- NEST VEIC Data Share 9Jun2017
- VT SF Existing Homes Onsite Report - DRAFT 122117
- hpwes-2-0-support-workbook-final-FY2020

Description

This characterization is in support of Efficiency Vermont's Home Performance with Energy Star Program. This characterization captures the impact associated with airsealing activities in a residence. This is a retrofit measure, saving energy by reducing air infiltration that would subsequently need to be heated by the primary heating system. Heating system characteristics, as well as actual pre and post work blower door results will be used to establish project level impacts. Blower door results will be mapped to one of three categories for the assignment of impact to enable prescriptive implementation of this measure. These categories are represented by a distinct CFM50 designation indicating improvement (reduction) in infiltration; 400, 1200, and 2000 CFM50. These values were chosed based on historic averages of HPwES project outcomes and represent 10%, 25% and 50% infiltration improvements of past program participants. Qualification for incentives requires a minimum of 10% reduction in infiltration.

Baseline Efficiencies

Home airtightness, as indicated by blower door testing(CFM50), prior to implementation of airsealing measures.

Efficient Equipment

Home airtightness, as indicated by blower door testing(CFM50), following implementation of airsealing measures.

Algorithms

Electric Demand Savings

Demand savings are exclusive to the heating season and the winter peak demand period. The total electric savings for each source (e.g., heat pump) resulting from airsealing are divided by the expected full load heating hours to establish the demand reduction. The loadhshape is subsequently used in conjunction with this value to establish winter peak demand savings.

$kW_{save} = kWh_{save} / EFLH_{eheat}$

Symbol Table

Energy Savings: Airsealing

This characterization limits the savings claim to the primary heating system only. Additionally, savings are limited to space heating savings. The savings calculations must be performed for the primary heating source, i.e., the system that contributes the largest proportion of heating load on a annual basis. An example at the end of this section illustrates how this characterization is used to claim savings.

$MMBtu_{save} = \beta_{CFM50} \times \psi \times SEAL_{20} \times HDH_n \times 60 \times c_p \times \rho / (\eta_{source} \times N_{heat} \times \omega)$

$kWh_{save} = \beta_{CFM50} \times \psi \times SEAL_{20} \times HDH_n \times 60 \times c_p \times \rho / (\eta_{source} \times N_{heat} \times \omega)$

Where:

β_{CFM50} = Infiltration improvement (CFM_{50}), as confirmed by blower door testing. The difference between pre and post readings will be used to map to one of three deemed values that will form the basis of savings, as outlined in the following table:

Blower Door Pre/Post Difference (CFM50)	Deemed Improvement for Impact Claim (CFM50)
>0 and <800	400
800 to <1600	1200
>1600	2000

η_{source} = Operating efficiency of the heating source[2][3], dependent of fuel and system type:

System/Fuel Type		Efficiency
Boiler	Oil	0.85
	Propane	0.874
Furnace	Oil	0.814
	Propane	0.90
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Cataylitic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Propane stove	0.65
	Heat Pump	2.93
	Electric Resistance	1.00

ω = Conversion factor from Btu to MMBtu or kWh, as appropriate
= 1,000,000 (Btu/MMBtu) or 3,412.14 (Btu/kWh)

ψ = Adjustment factor to bring savings estimates given by this simplified algorithm to evaluation bill anaylsis results.[4]
= 0.55 (dimensionless)

ρ = Density of air at prevalent conditions during the heating season (lb/ft^3)
= 0.0749 (lb/ft^3)

60 = Converts volumitric air flow per minute to hour
= 60 (minutes/hour)

c_p = Specific heat of air at prevalent conditions during the heating season (Btu/lb F)
= 0.24 (Btu/lb F)

$EFLH_{eheat}$ = Effective Full Load Hours for electric heating source (hours)
= 1,383 (hours)[1]

HDH_n = Heating Degree Hours[5], calculated as the average of flat, open attic (127,691.3 [F hr]) and basement/crawlspace rim joists and walls (99,194.6 [F hr]):

		= 113,443.0 (F hr)
kW_{save}	=	Electric demand savings (kW)
kWh_{save}	=	Annual elecric energy savings (kWh)
$MMBtu_{save}$	=	Annual fuel savings (MMBtu)
N_{heat}	=	Conversion factor from volumetric air flow at 50 Pascal pressure to natural conditions[6] = 20 (dimensionless)
$SEAL_{20}$	=	Realization Rate from 2020 sampling of projects[7] = 1.06925303531848

The following table summarizes the savings outcomes for all prescriptive savings possibilities. To exemplify how savings shall be claimed, let's assume a project has achieved 1350 CFM50 infiltration improvement, as shown by blower door testing. The site has a primary propane furnace.

1350 CFM50 blower door pre/post difference maps to a deemed value of 1200 CFM50 improvement, itemcode HPSEAL12BOILPROP, which has **4.940 MMBtu** savings associated with it.

Summarized Savings Outcomes

System/Fuel Type		CFM50 Improvement	MMBtu Savings	kWh Savings	kW Savings	Itemcode
Boiler	Oil	>0 and <800	1.693			HPSEAL4BOILOIL
		800 to <1600	5.079			HPSEAL12BOILOIL
		>1600	8.465			HPSEAL20BOILOIL
	Propane	>0 and <800	1.647			HPSEAL4BOILPROP
		800 to <1600	4.940			HPSEAL12BOILPROP
		>1600	8.233			HPSEAL20BOILPROP
Furnace	Oil	>0 and <800	1.768			HPSEAL4FURNOIL
		800 to <1600	5.304			HPSEAL12FURNOIL
		>1600	8.840			HPSEAL20FURNOIL
	Propane	>0 and <800	1.599			HPSEAL4FURNPROP
		800 to <1600	4.797			HPSEAL12FURNPROP
		>1600	7.995			HPSEAL20FURNPROP
Other	Pellet stove	>0 and <800	2.056			HPSEAL4PLLTWOOD
		800 to <1600	6.168			HPSEAL12PLLTWOOD
		>1600	10.279			HPSEAL20PLLTWOOD
	Newer EPA woodstove	>0 and <800	2.399			HPSEAL4EPAWWOOD
		800 to <1600	7.196			HPSEAL12EPAWWOOD
		>1600	11.993			HPSEAL20EPAWWOOD
	Cataylitic woodstove	>0 and <800	2.878			HPSEAL4CATWWOOD
		800 to <1600	8.635			HPSEAL12CATWWOOD
		>1600	14.391			HPSEAL20CATWWOOD
	Non-catalytic woodstove	>0 and <800	3.598			HPSEAL4NCATWOOD
		800 to <1600	10.793			HPSEAL12NCATWOOD
		>1600	17.989			HPSEAL20NCATWOOD
	Outdoor wood boiler	>0 and <800	5.756			HPSEAL4ODWBWOOD
		800 to <1600	17.269			HPSEAL12ODWBWOOD
		>1600	28.782			HPSEAL20ODWBWOOD
	Open hearth fireplace	>0 and <800	14.391			HPSEAL4OHFPWOOD
		800 to <1600	43.173			HPSEAL12OHFPWOOD
		>1600	71.956		`	HPSEAL20OHFPWOOD
	Propane stove	>0 and <800	2.214			HPSEAL4STVEPROP
		800 to <1600	6.642			HPSEAL12STVEPROP
		>1600	11.070			HPSEAL20STVEPROP
	Heat Pump	>0 and <800		143.9	0.10405	HPSEAL4HPMPELEC
		800 to <1600		431.7	0.31215	HPSEAL12HPMPELEC
		>1600		719.6	0.52032	HPSEAL20HPMPELEC
	Electric Resistance	>0 and <800		421.8	0.30499	HPSEAL4ERESELEC
		800 to <1600		1265.3	0.9149	HPSEAL12ERESELEC
		>1600		2108.8	1.5248	HPSEAL20ERESELEC

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%

Net Savings Factors

Measures

TSHAIRSL	Airsealing

Tracks [Base Track]

6036HPES [6036RETR]	HPwES EVT

Lifetimes

Lifetime for airsealing measures is 20 years.[8]

Measure Cost

Total measure costs of $3,000 are used ***as a placeholder value***, to be trued up at year-end closeout with actual invoiced project cost averages for airsealing work.[9]:

Footnotes

[1] $EFLH_{eheat}$ is taken to be the established full load hours for a heat pump under the premise that the majority of any eletric heat sources are likely to be heat pumps. Further, as this value is higher than the default EFLH for the loadshape applicable to this measure, the demand savings err on the conservative side. This value is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. See TRM measure Variable Speed Mini-Split Heat Pumps (Market Opportunity) for additional background and reference documents.

[2] Boiler and furnace efficiencies are the median values reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 in Tables 46 and 47. Heat pump efficiency conservatively taken to be the minimum qualifying efficiency requirement for EVT's programs, HSPF = 10.0, converted to COP by dividing by 3.41214.

Pellet stove: The EPA Certified Wood Heater Database, which only lists EPA compliant models, indicates that the average modern pellet stove – year 2017 and newer – on average operates at about 73% efficiency. To accommodate older models and non-compliant models it is reasonable to assume 70% efficiency for the pellet stove category.

"Newer EPA Woodstove" refers to units sold after July 1, 1992 when Phase 2 particulate emissions standards became effective (4.1 g/hr for catalytic stoves and 7.5 g/hr for non-catalytic stoves). These units characteristically have better efficiencies than older or non-compliant units. The EPA Certified Wood Heater Database, which only lists efficiencies for qualifying models dated back to 2015, indicates that the modern woodstove performs at about 73% efficiency. Given that performance has increased since the 1992 standard and considering stove maintenance realities – per DOE, even one-tenth of an inch of soot buildup on stove internals can drop heat transfer efficiency of the metal by 50% – it is fully reasonable to assume the general "Newer EPA Woodstove" category operates with 60% efficiency.

Catalytic & Non-catalytic woodstoves: According to the EPA, certified stoves can be 50% more efficient than non-certified units. Additionally, since non-certified units produce more particulate emissions, it follows that soot buildup likely plays a stronger influence on efficiency. Taken together, it is reasonable to assume the worst performing category of woodstoves, non-catalytic, operates at 40% efficiency. Per the EPA Certified Wood Heater Database, modern catalytic woodstoves have about a 6% efficiency advantage on average, compared to non-catalytic models. It is therefore reasonable to assume that the catalytic woodstove category operates at 50% efficiency, squarely between newer EPA woodstoves and non-catalytic woodstoves.

Outdoor wood boiler: The EPA Certified Wood Heater Database lists average efficiency ratings for cord wood fired hydronic central heaters at 67%, however this does not account for heat hydronic heat transfer efficiencies, or the fact that outdoor boilers are often fueled with green/wet firewood, which can have half the heating value of properly seasoned wood. Soot buildup is also a common issue in outdoor wood boilers, which further inhibits heat transfer and reduces efficiency. System design, such as pipe lengths, are also critical to consider, but impossible to generalize. The culmination of these factors leads to a reasonable assumption of 25% efficiency for a typical central wood boiler, although in practice efficiencies could be much higher or lower.

***See continuation below in reference 8199*

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[3] Open hearth fireplace: values of up to 10% are commonly referenced. DOE and the EPA do not cite specific numbers, but do caution "Generally, a wood-burning fireplace is a very inefficient way to heat your home. Fireplace drafts can pull the warm air up the chimney, causing other rooms to be cooler. If you use central heat while burning in a fireplace, your heater will work harder to maintain constant temperatures throughout the house" and "Traditional fireplaces draw in as much as 300 cubic feet per minute of heated room air for combustion, then send it straight up the chimney… Although some fireplace designs seek to address these issues with dedicated air supplies, glass doors, and heat recovery systems, most traditional fireplaces are still energy losers." When used as primary heat source, a 10% efficiency is a reasonable assumption.

Propane stove: Modern vented gas stoves can achieve efficiencies close to non-condensing furnaces, however to account for aged equipment as well as products such as fireplace inserts, an efficiency of 65% is deemed appropriate.

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[4] This adjustment factor mirrors that which is applied to HERO-based HPwES projects. Based on the 2018 program impact evaluation and subsequent outcomes of EM&V/DPS negotiations, the 0.55 adjustment factor is intended to better align the savings estimated by HERO algorithms to those established by evaluation. Since the algorithms used by this characterization closely align with HERO, the same adjustment factor is adopted.

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[5] Heating Degree Hours for attic assumes a base temperature of 58 degrees F and uses Climate Normals data for Burlington Internation Airport. A recent Nest study by EVT revealed that a base temperature of 58 degrees is appropriate to capture the heating tendencies of a typical Vermont home. See referenced document "NEST VEIC Data Share 9Jun2017." In an attempt to make a conservative estimate of heating degree hours, it was assumed that only days within a defined heating season would be included in the total, assuming that homeowners would disable or set back heating systems in the off season. The heating season was defined as the time period where temperatures "consistently" fall below 58 degrees. Based on visual inspection of TMY3 data, this period was established as September 19th to May 6th. Heating Degree Hours for basement assumes a blend of conditioned and unconditioned space as reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Unconditioned space HDH assumes a base temperature of 48 degrees F based on the premise that unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool. See worksheets "Foundation Blend" and "HDH - Climate Normals" in the HPwES 2.0 Support Workbook FINAL for a complete derivation.

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[6] A legacy negotiated value carried over from a historic EVT Home Performance With Energy Star program performance evaluation finding intended to bring savings predicted by this algorithm in line with evaluated impacts.

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[7] EVT performed a sampling of 35 FY2020 projects. Contractors were interviewed and desk reviews of projects were completed to evaluate measure realization rates. Airsealing realization rate established by using TRM-based algorithms and actual reported (and/or verified) pre/post blower door numbers.

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[8] Lifetime consistent with Tracker assumptions.

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[9] Due to highly variable scopes and approaches to airsealing, EVT will use actual cost data collected for a particular performance year to perform a year-end adjustment to deemed costs to align with actual average costs.

HPwES 2.0 Insulation: Exterior Walls

Measure Number: VII-K-3 b
Portfolio:
Status: Active
Effective Date: 2019/1/1
End Date: [None]
Program: Existing Homes
End Use: Thermal Shell

Update Summary

This is a new Efficiency Vermont offering for the Home Performance with Energy Star program and version one of the characterization.

Referenced Documents

- NEST VEIC Data Share 9Jun2017
- VT SF Existing Homes Onsite Report - DRAFT 122117
- R-values common building materials
- hpwes-2-0-support-workbook-final-FY2020

Description

This characterization is in support of Efficiency Vermont's Home Performance with Energy Star Program. This characterization captures the impact associated with blown-in wall insulation activities in a residence. This is a retrofit measure, savings energy by increasing the thermal resistance of structural exterior wall assemblies. Heating system characteristics, as well as preexisting thermal resistance properties will be used to establish project level impacts. Preexisting insulation levels will be evaluated and deemed as either "No Insulation" (indicating the wall assembly is completely void of thermal insulation material) or "Existing Insulation" (indicating the wall assemble contains any amount of thermal insulation material) to enable prescriptive implementation of this measure. Post insulation levels assume maximum potential nominal insulation performance is achieved - nominal R13 in 2x4 wall construction and R19 in 4x6 construction[1]. ***Note: this characterization captures the impacts associated with 100 SQFT of wall insulation work, exclusive of glazing. Projects will claim multiple quantities of measures, depending on how much wall insulation work is done.***

Baseline Efficiencies

Baseline conditions are defined by the thermal resistance properties of the existing wall assembly. Two baseline wall assemblies are considered within this characterization: a wall assembly with zero non-structural insulation material and a wall assembly with any amount of non-structural insulation material.

Efficient Equipment

Efficient conditions are defined by the improved thermal resistance properties of a wall assembly after blown-insulation work has been performed. It is assumed that nominal insulation ratings are achieved. Because insulation work is limited to non-destructive methods, wall cavity thickness dictates improvement limits. Assuming cellulose, fiberglass, or rock wool insulation is used, this limits the theoretical nominal R value ratings to approximately R13 for 2x4 stud construction and R19 for 2x6 construction. Ultimately, a single blended value for an improved wall condition is assumed within this characterization.

Algorithms

Electric Demand Savings

Demand savings are exclusive to the heating season and the winter peak demand period. The total electric savings for each source (e.g., heat pump) resulting from insulating are divided by the expected full load heating hours to establish the demand reduction. The loadhshape is subsequently used in conjunction with this value to establish winter peak demand savings.

$$kW_{save} = kWh_{save} / EFLH_{eheat}$$

Symbol Table

Energy Savings: Insulation

This characterization limits the savings claim to the primary heating system only. Additionally, savings are limited to space heating savings. The savings calculations must be performed for the primary heating source, i.e., the system that contributes the largest proportion of heating load on a annual basis. An example at the end of this section illustrates how this characterization is used to claim savings.

$$MMBtu_{save} = (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi \times WALL_{20} / (\eta_{source} \times \omega)$$

$$kWh_{save} = (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi \times WALL_{20} / (\eta_{source} \times \omega)$$

Where:

η_{source} = Operating efficiency of the heating source[3][4], dependent of fuel and system type:

System/ Fuel Type		Efficiency
Boiler	Oil	0.85
	Propane	0.874
Furnace	Oil	0.814
	Propane	0.90
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Cataylitic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Propane stove	0.65
	Heat Pump	2.93
	Electric Resistance	1.00

ω = Conversion factor from Btu to MMBtu or kWh, as appropriate
= 1,000,000 (Btu/MMBtu) or 3,412.14 (Btu/kWh)

ψ = Adjustment factor to bring savings estimates given by this simplified algorithm to evaluation bill anaylsis results.[5]
= 0.55 (dimensionless)

$EFLH_{eheat}$ = Effective Full Load Hours for electric heating source (hours)
= 1,383 (hours)[2]

HDH_n = Heating Degree Hours[6], (F hr):
= 127,691.3 (F hr)

kW_{save} = Electric demand savings (kW)

kWh_{save} = Annual elecric energy savings (kWh)

$MMBtu_{save}$ = Annual fuel savings (MMBtu)

R_{post} = Thermal resistance of the improved (post-treatment) wall assemblies separating conditioned space to the ambient environment (hr F ft^2/Btu)[7]:
= 11.85797 (hr F ft^2/Btu)

R_{pre} = Thermal resistance of the existing (pre-treatment) exterior wall assembly separating conditioned space to the ambient environment (hr F ft^2/Btu). Based on the presence of insulation, a yes/no determination[8]:

Walls	
Evaluated Existing Insulation Condition	**Deemed Wall Asembly R-Value for Impact Claim**
No Insulation	2.58593
Existing Insulation	10.55070

SF_n = Area of treatment with improved insulation properties

= 100 (ft^2)

$WALL_{20}$ = Realization Rate from 2020 sampling of projects, dependent on claimed existing wall insulation level[9]

Evaluated Existing Insulation Condition	$WALL_{20}$
No Insulation	0.659243635788118
Existing Insulation	1.0

The following table summarizes the savings outcomes for each heating system type, and fuel type. To exemplify how savings shall be claimed, let's assume a project has insulated 100 ft^2 of wall area and had no existing insulation. The site has a primary propane furnace. Itemcode HPWINS0FURNPROP indicates this project would have **1.556 MMBtu** savings associated with wall insulation work. Alternatively, if that same project had insulated 300 ft^2 of wall area, a quantity of three measures would be claimed for a total of 3 x 1.556 = 4.668 MMBtu propane savings.

Summarized Savings Outcomes

System/Fuel Type		Pre R-Value	MMBtu Savings	kWh Savings	kW Savings	Itemcode
Boiler	Oil	No Insulation	1.647			HPWINS0BOILOIL
		Existing Insulation	0.086			HPWINSG2BOILOIL
	Propane	No Insulation	1.602			HPWINS0BOILPROP
		Existing Insulation	0.084			HPWINSG2BOILPROP
Furnace	Oil	No Insulation	1.720			HPWINS0FURNOIL
		Existing Insulation	0.090			HPWINSG2FURNOIL
	Propane	No Insulation	1.556			HPWINS0FURNPROP
		Existing Insulation	0.082			HPWINSG2FURNPROP
Other	Pellet stove	No Insulation	2.000			HPWINS0PLLTWOOD
		Existing Insulation	0.105			HPWINSG2PLLTWOOD
	Newer EPA woodstove	No Insulation	2.333			HPWINS0EPAWWOOD
		Existing Insulation	0.122			HPWINSG2EPAWWOOD
	Cataylitic woodstove	No Insulation	2.800			HPWINS0CATWWOOD
		Existing Insulation	0.147			HPWINSG2CATWWOOD
	Non-catalytic woodstove	No Insulation	3.500			HPWINS0NCATWOOD
		Existing Insulation	0.183			HPWINSG2NCATWOOD
	Outdoor wood boiler	No Insulation	5.600			HPWINS0ODWBWOOD
		Existing Insulation	0.294			HPWINSG2ODWBWOOD
	Open hearth fireplace	No Insulation	14.000			HPWINS0OHFPWOOD
		Existing Insulation	0.734			HPWINSG2OHFPWOOD
	Propane stove	No Insulation	2.154			HPWINS0STVEPROP
		Existing Insulation	0.113			HPWINSG2STVEPROP
	Heat Pump	No Insulation		140	0.10123	HPWINS0HPMPELEC
		Existing Insulation		7.3	0.00528	HPWINSG2HPMPELEC
	Electric Resistance	No Insulation		410.3	0.29667	HPWINS0ERESELEC
		Existing Insulation		21.5	0.01555	HPWINSG2ERESELEC

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%

Net Savings Factors

Measures

TSHNACWL	Attic/ceiling/wall insulation

Tracks [Base Track]

6036HPES [6036RETR]	HPwES EVT

Lifetimes

Lifetime for wall insulation is 30 years.[10]

Measure Cost

Measure costs of $200 are used ***as a placeholder value*** for 100 ft^2 wall insulation.

All costs will be trued up at year-end closeout with actual invoiced project cost averages for insulation work.[11]:

Footnotes

[1] Per the 2017 Existing Homes Onsite Report, these two construction types represent 86% of homes in EVT territory. Given that an additional 7% of homes use 24" center construction, this characterization assumes that 16" center construction conservatively represents at least 93% of homes. Therefore these two wall types are used to determine an acceptable deemed assumption representing any wall type participating in the program.

[2] $EFLH_{eheat}$ is taken to be the established full load hours for a heat pump under the premise that the majority of any eletric heat sources are likely to be heat pumps. Further, as this value is higher than the default EFLH for the loadshape applicable to this measure, the demand savings err on the conservative side. This value is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. See TRM measure Variable Speed Mini-Split Heat Pumps (Market Opportunity) for additional background and reference documents.

[3] Boiler and furnace efficiencies are the median values reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 in Tables 46 and 47. Heat pump efficiency conservatively taken to be the minimum qualifying efficiency requirement for EVT's programs, HSPF = 10.0, converted to COP by dividing by 3.41214.

Pellet stove: The EPA Certified Wood Heater Database, which only lists EPA compliant models, indicates that the average modern pellet stove – year 2017 and newer – on average operates at about 73% efficiency. To accommodate older models and non-compliant models it is reasonable to assume 70% efficiency for the pellet stove category.

"Newer EPA Woodstove" refers to units sold after July 1, 1992 when Phase 2 particulate emissions standards became effective (4.1 g/hr for catalytic stoves and 7.5 g/hr for non-catalytic stoves). These units characteristically have better efficiencies than older or non-compliant units. The EPA Certified Wood Heater Database, which only lists efficiencies for qualifying models dated back to 2015, indicates that the modern woodstove performs at about 73% efficiency. Given that performance has increased since the 1992 standard and considering stove maintenance realities – per DOE, even one-tenth of an inch of soot buildup on stove internals can drop heat transfer efficiency of the metal by 50% – it is fully reasonable to assume the general “Newer EPA Woodstove” category operates with 60% efficiency.

Catalytic & Non-catalytic woodstoves: According to the EPA, certified stoves can be 50% more efficient than non-certified units. Additionally, since non-certified units produce more particulate emissions, it follows that soot buildup likely plays a stronger influence on efficiency. Taken together, it is reasonable to assume the worst performing category of woodstoves, non-catalytic, operates at 40% efficiency. Per the EPA Certified Wood Heater Database, modern catalytic woodstoves have about a 6% efficiency advantage on average, compared to non-catalytic models. It is therefore reasonable to assume that the catalytic woodstove category operates at 50% efficiency, squarely between newer EPA woodstoves and non-catalytic woodstoves.

Outdoor wood boiler: The EPA Certified Wood Heater Database lists average efficiency ratings for cord wood fired hydronic central heaters at 67%, however this does not account for heat hydronic heat transfer efficiencies, or the fact that outdoor boilers are often fueled with green/wet firewood, which can have half the heating value of properly seasoned wood. Soot buildup is also a common issue in outdoor wood boilers, which further inhibits heat transfer and reduces efficiency. System design, such as pipe lengths, are also critical to consider, but impossible to generalize. The culmination of these factors leads to a reasonable assumption of 25% efficiency for a typical central wood boiler, although in practice efficiencies could be much higher or lower.

***See continuation below in reference 8201*

[4] Open hearth fireplace: values of up to 10% are commonly referenced. DOE and the EPA do not cite specific numbers, but do caution “Generally, a wood-burning fireplace is a very inefficient way to heat your home. Fireplace drafts can pull the warm air up the chimney, causing other rooms to be cooler. If you use central heat while burning in a fireplace, your heater will work harder to maintain constant temperatures throughout the house” and “Traditional fireplaces draw in as much as 300 cubic feet per minute of heated room air for combustion, then send it straight up the chimney… Although some fireplace designs seek to address these issues with dedicated air supplies, glass doors, and heat recovery systems, most traditional fireplaces are still energy losers.” When used as primary heat source, a 10% efficiency is a reasonable assumption.

Propane stove: Modern vented gas stoves can achieve efficiencies close to non-condensing furnaces, however to account for aged equipment as well as products such as fireplace inserts, an efficiency of 65% is deemed appropriate.

[5] This adjustment factor mirrors that which is applied to HERO-based HPwES projects. Based on the 2018 program impact evaluation and subsequent outcomes of EM&V/DPS negotiations, the 0.55 adjustment factor is intended to better align the savings estimated by HERO algorithms to those established by evaluation. Since the algorithms used by this characterization closely align with HERO, the same adjustment factor is adopted.

[6] Heating Degree Hours for attic assumes a base temperature of 58 degrees F and uses Climate Normals data for Burlington Internation Airport. A recent Nest study by EVT revealed that a base temperature of 58 degrees is appropriate to capture the heating tendencies of a typical Vermont home. See referenced document "NEST VEIC Data Share 9Jun2017." In an attempt to make a conservative estimate of heating degree hours, it was assumed that only days within a defined heating season would be included in the total, assuming that homeowners would disable or set back heating systems in the off season. The heating season was defined as the time period where temperatures "consistently" fall below 58 degrees. Based on visual inspection of TMY3 data, this period was established as September 19th to May 6th. Heating Degree Hours for basement assumes a blend of conditioned and unconditioned space as reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Unconditioned space HDH assumes a base temperature of 48 degrees F based on the premise that unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool. See worksheets "Foundation Blend" and "HDH - Climate Normals" in the HPwES 2.0 Support Workbook FINAL_walls for a complete derivation.

[7] This value is a weighted blend of near perfect (Grade I) insulated wall assemblies using 2x4 and 2x6 studs 16" on center construction. Per the existing home report, this construction represents 86% of homes in EVT territory. Given that an additional 7% of homes use 24" center construction, this characterization assumes that 16" center construction conservatively represents at least 93% of homes. It is therefore taken to be an acceptable deemed assumption for any wall type participating in the program. For a full derivation, see the worksheet "Walls" in reference document HPwES 2.0 Support Workbook FINAL_walls. Note that this number reflects the r-value of insulation as well as all other assembly materials.

[8] Existing Insulation deemed value is a weighted blend of Grade II and Grade III (as defined by the 2017 Existing Homes Onsite Report) insulated wall assemblies using 2x4 and 2x6 studs 16" on center construction. Per the report, Grade II and Grade III ratings represent 100% of existing wall area in EVT territory. Grade II insulation assumes 1% of insulation area is comprised of gaps and Grade III assumes 3.5%. For a full derivation of "No Insulatio" and "Existing Insulaiton" assembly assumptions, see the worksheet "Walls" in reference document HPwES 2.0 Support Workbook FINAL_walls. Note that final number reflects the r-value of insulation as well as all other assembly materials and air gaps.

[9] EVT performed a sampling of 35 FY2020 projects. Contractors were interviewed and desk reviews of projects were completed to evaluate measure realization rates. Wall insulation realization rate established by using TRM-based algorithms with verified variable inputs.

[10] Lifetimes consistent with Tracker assumptions.

[11] Due to highly variable scopes and approaches to insulating, EVT will use actual cost data collected for a particular performance year to perform a year-end adjustment to deemed costs to align with actual average costs.

HPwES 2.0 Insulation: Attic and/or Basement

Measure Number:	VII-K-2 g
Portfolio:	
Status:	Active
Effective Date:	2021/1/1
End Date:	[None]
Program:	Existing Homes
End Use:	Thermal Shell

Update Summary

Updated Attic insulation RR for 2021 to reflect improved efforts to collect more documentation.

Referenced Documents

- NEST VEIC Data Share 9Jun2017
- VT SF Existing Homes Onsite Report - DRAFT 122117
- hpwes-2-0-support-workbook-final-FY2020

Description

This characterization is in support of Efficiency Vermont's Home Performance with Energy Star Program. This characterization captures the impact associated with open attic and/or basement/crawlspace rim joist and wall insulation activities in a residence. This is a retrofit measure, saving energy by savings energy by increasing the thermal resistance of structural assemblies. Heating system characteristics, as well as actual pre and post thermal resistance properties will be used to establish project level impacts. Pre-existing insulation levels (post assumes current RBES code minimum requirements are met) will be mapped to one of three categories for the assignment of impact to enable prescriptive implementation of this measure. In order for insulation work to be incentivized, existing basement insulation must have a nominal rating of R10 or lower, and attic insulation R30 or lower.

Baseline Efficiencies

Baseline conditions are defined by the overall weighted nominal insulation R-value of existing insulation.

Efficient Equipment

Current Vermont Residential Building Energy Standards minimum requrements define the efficient conditions for both insulation measures.

For open attics, the efficient condition upgrades the insulation properties of the attic assembly by achieving an overall weighted nominal insulation R-value of R-49.

For basements, an overall weighted nominal insulation R-value of R-15 defines the efficient condition.

Algorithms

Electric Demand Savings

Demand savings are exclusive to the heating season and the winter peak demand period. The total electric savings for each source (e.g., heat pump) resulting from insulating are divided by the expected full load heating hours to establish the demand reduction. The loadhshape is subsequently used in conjunction with this value to establish winter peak demand savings.

kW_{save}	$= kWh_{save} / EFLH_{eheat}$

Symbol Table

Energy Savings: Insulation

This characterization limits the savings claim to the primary heating system only. Additionally, savings are limited to space heating savings. The savings calculations must be performed for the primary heating source, i.e., the system that contributes the largest proportion of heating load on a annual basis. An example at the end of this section illustrates how this characterization is used to claim savings.

$MMBtu_{save}$	$= (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi \times RR_{20} / (\eta_{source} \times \omega)$
kWh_{save}	$= (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi \times RR_{20} / (\eta_{source} \times \omega)$

Where:

η_{source} = Operating efficiency of the heating source[2][3], dependent of fuel and system type:

System/Fuel Type		Efficiency
Boiler	Oil	0.85
	Propane	0.874
Furnace	Oil	0.814
	Propane	0.90
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Cataylitic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Propane stove	0.65
	Heat Pump	2.93
	Electric Resistance	1.00

ω = Conversion factor from Btu to MMBtu or kWh, as appropriate

= 1,000,000 (Btu/MMBtu) or 3,412.14 (Btu/kWh)

ψ = Adjustment factor to bring savings estimates given by this simplified algorithm to evaluation bill anaylsis results.[4]

= 0.55 (dimensionless)

$EFLH_{eheat}$ = Effective Full Load Hours for electric heating source (hours)

= 1,383 (hours)[1]

HDH_n = Heating Degree Hours[5], dependent on space being treated (F hr):

= 127,691.3 (F hr) for flat, open attic OR 99,194.6 (F hr) for basement/crawlspace rim joists and walls

kW_{save} = Electric demand savings (kW)

kWh_{save} = Annual elecric energy savings (kWh)

$MMBtu_{save}$ = Annual fuel savings (MMBtu)

R_{post} = Thermal resistance of the improved (post-treatment) assemblies separating conditioned space to the ambient environment[6], dependent on space being treated (hr F ft^2/Btu):

= 49.0 (hr F ft^2/Btu) for flat, open attic OR 22.4 (hr F ft^2/Btu) for basement/crawlspace rim joists and walls

R_{pre} = Thermal resistance of the insulation on/in existing (pre-treatment) assemblies separating conditioned space to the ambient environment[7], dependent on space being treated (hr F ft^2/Btu). Reported ratings will map to one of three deemed values that will form the basis of savings, as outlined in the following table:

Attic		**Basement**	
Evaluated Existing R-Value	**Deemed R-Value for Impact Claim**	**Evaluated Existing R-Value***	**Deemed R-Value for Impact Claim****
Below 10	5	Below 3	8.5
10 to 20	15	3 to 7	12.2
Above 20	25	Above 7	15.8

* Does not include thermal resistance properties of soil

** Includes thermal resistance properties of soil. For reference, the root assumptions of nominal R-values for the insulation only are 1.5, 5 and 8.5 (hr F ft^2/Btu) respectively.

RR_{20} = Realization Rate from 2020 sampling of projects, dependent on space type and claimed existing insulation level[8]

Attic		Basement	
Evaluated Existing R-Value	**RR_{20}**	**Evaluated Existing R-Value***	**RR_{20}**
Below 10	0.40	Below 3	0.303456151518978
10 to 20	1.0	3 to 7	1.0
Above 20	1.0	Above 7	1.0

SF_n = Area of treatment with improved insulation properties[9]

= 852.87 (ft^2) for flat, open attic OR 967.59 (ft^2) for basement/crawlspace rim joists and walls

The following table summarizes the savings outcomes for each treatment area, treatment activity, heating system type, and fuel type. To exemplify how savings shall be claimed, let's assume a project has insulated an open attic and had existing R-25 nominally rated insulation. The site has a primary propane furnace. R-28 existing insulation maps to a deemed value of R-25, itemcode HPAINS15FURNOIL which has **3.079 MMBtu** savings associated with it.

Summarized Savings Outcomes

Attic

System/Fuel Type		Pre R-Value	MMBtu Savings	kWh Savings	kW Savings	Itemcode
Boiler	Oil	<10	5.062			HPAINS5BOILOIL
		10 to 20	3.260			HPAINS15BOILOIL
		>20	1.381			HPAINS25BOILOIL
	Propane	<10	4.923			HPAINS5BOILPROP
		10 to 20	3.170			HPAINS15BOILPROP
		>20	1.343			HPAINS25BOILPROP
Furnace	Oil	<10	5.286			HPAINS5FURNOIL
		10 to 20	3.404			HPAINS15FURNOIL
		>20	1.442			HPAINS25FURNOIL
	Propane	<10	4.781			HPAINS5FURNPROP
		10 to 20	3.079			HPAINS15FURNPROP
		>20	1.304			HPAINS25FURNPROP
Other	Pellet stove	<10	6.147			HPAINS5PLLTWOOD
		10 to 20	3.958			HPAINS15PLLTWOOD
		>20	1.676			HPAINS25PLLTWOOD
	Newer EPA woodstove	<10	7.171			HPAINS5EPAWWOOD
		10 to 20	4.618			HPAINS15EPAWWOOD
		>20	1.956			HPAINS25EPAWWOOD
	Cataylitic woodstove	<10	8.606			HPAINS5CATWWOOD
		10 to 20	5.542			HPAINS15CATWWOOD
		>20	2.347			HPAINS25CATWWOOD
	Non-catalytic woodstove	<10	10.757			HPAINS5NCATWOOD
		10 to 20	6.927			HPAINS15NCATWOOD
		>20	2.934			HPAINS25NCATWOOD
	Outdoor wood boiler	<10	17.211			HPAINS5ODWBWOOD
		10 to 20	11.083			HPAINS15ODWBWOOD
		>20	4.694			HPAINS25ODWBWOOD
	Open hearth fireplace	<10	43.028			HPAINS5OHFPWOOD
		10 to 20	27.708			HPAINS15OHFPWOOD
		>20	11.735			HPAINS25OHFPWOOD
		<10	6.620			HPAINS5STVEPROP

	Propane stove	10 to 20	4.263			HPAINS15STVEPROP
		>20	1.805			HPAINS25STVEPROP
	Heat Pump	<10		430.1	0.31102	HPAINS5HPMPELEC
		10 to 20		277.1	0.20036	HPAINS15HPMPELEC
		>20		117.4	0.08489	HPAINS25HPMPELEC
	Electric Resistance	<10		1261.0	0.91179	HPAINS5ERESELEC
		10 to 20		812.0	0.58713	HPAINS15ERESELEC
		>20		343.9	0.24866	HPAINS25ERESELEC

Basement

System/Fuel Type		Pre R-Value	MMBtu Savings	kWh Savings	kW Savings	Itemcode
Boiler	Oil	<3	1.380			HPBINS8BOILOIL
		3 to 7	2.313			HPBINS12BOILOIL
		>7	1.156			HPBINS16BOILOIL
	Propane	<3	1.342			HPBINS8BOILPROP
		3 to 7	2.249			HPBINS12BOILPROP
		>7	1.124			HPBINS16BOILPROP
Furnace	Oil	<3	1.441			HPBINS8FURNOIL
		3 to 7	2.415			HPBINS12FURNOIL
		>7	1.207			HPBINS16FURNOIL
	Propane	<3	1.303			HPBINS8FURNPROP
		3 to 7	2.184			HPBINS12FURNPROP
		>7	1.092			HPBINS16FURNPROP
Other	Pellet stove	<3	1.676			HPBINS8PLLTWOOD
		3 to 7	2.808			HPBINS12PLLTWOOD
		>7	1.404			HPBINS16PLLTWOOD
	Newer EPA woodstove	<3	1.955			HPBINS8EPAWWOOD
		3 to 7	3.276			HPBINS12EPAWWOOD
		>7	1.637			HPBINS16EPAWWOOD
	Cataylitic woodstove	<3	2.346			HPBINS8CATWWOOD
		3 to 7	3.931			HPBINS12CATWWOOD
		>7	1.965			HPBINS16CATWWOOD
	Non-catalytic woodstove	<3	2.932			HPBINS8NCATWOOD
		3 to 7	4.914			HPBINS12NCATWOOD
		>7	2.456			HPBINS16NCATWOOD
	Outdoor wood boiler	<3	4.692			HPBINS8ODWBWOOD
		3 to 7	7.863			HPBINS12ODWBWOOD
		>7	3.930			HPBINS16ODWBWOOD
	Open hearth fireplace	<3	11.729			HPBINS8OHFPWOOD
		3 to 7	19.657			HPBINS12OHFPWOOD
		>7	9.825			HPBINS16OHFPWOOD
	Propane stove	<3	1.804			HPBINS8STVEPROP
		3 to 7	3.024			HPBINS12STVEPROP
		>7	1.512			HPBINS16STVEPROP
	Heat Pump	<3		117.3	0.08482	HPBINS8HPMPELEC
		3 to 7		196.6	0.14215	HPBINS12HPMPELEC
		>7		98.2	0.07101	HPBINS16HPMPELEC
	Electric Resistance	<3		343.7	0.24852	HPBINS8ERESELEC
		3 to 7		576.1	0.41656	HPBINS12ERESELEC
		>7		287.9	0.20817	HPBINS16ERESELEC

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9%	57.1%	0.0%	0.0%	25.0%	0.0%

Net Savings Factors

Measures

TSHNACWL	Attic/ceiling/wall insulation
TSHNFNDN	Foundation insulation, interior

Tracks [Base Track]

6036HPES [6036RETR]	HPwES EVT

Lifetimes

Lifetime for attic insulation is 30 years.[10]

Lifetime for basement insulation is 15 years.

Measure Cost

Measure costs of $3,000 are used ***as a placeholder value*** for attic insulation.

Measure costs of $3,000 are used ***as a placeholder value*** for basement insulation.

All costs will be trued up at year-end closeout with actual invoiced project cost averages for airsealing work.[11]:

Footnotes

[1] $EFLH_{eheat}$ is taken to be the established full load hours for a heat pump under the premise that the majority of any eletric heat sources are likely to be heat pumps. Further, as this value is higher than the default EFLH for the loadshape applicable to this measure, the demand savings err on the conservative side. This value is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. See TRM measure Variable Speed Mini-Split Heat Pumps (Market Opportunity) for additional background and reference documents.

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Pellet stove: The EPA Certified Wood Heater Database, which only lists EPA compliant models, indicates that the average modern pellet stove – year 2017 and newer – on average operates at about 73% efficiency. To accommodate older models and non-compliant models it is reasonable to assume 70% efficiency for the pellet stove category.

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***See continuation below in reference 8200*

[3] Open hearth fireplace: values of up to 10% are commonly referenced. DOE and the EPA do not cite specific numbers, but do caution "Generally, a wood-burning fireplace is a very inefficient way to heat your home. Fireplace drafts can pull the warm air up the chimney, causing other rooms to be cooler. If you use central heat while burning in a fireplace, your heater will work harder to maintain constant temperatures throughout the house" and "Traditional fireplaces draw in as much as 300 cubic feet per minute of heated room air for combustion, then send it straight up the chimney… Although some fireplace designs seek to address these issues with dedicated air supplies, glass doors, and heat recovery systems, most traditional fireplaces are still energy losers." When used as primary heat source, a 10% efficiency is a reasonable assumption.

Propane stove: Modern vented gas stoves can achieve efficiencies close to non-condensing furnaces, however to account for aged equipment as well as products such as fireplace inserts, an efficiency of 65% is deemed appropriate.

[4] This adjustment factor mirrors that which is applied to HERO-based HPwES projects. Based on the 2018 program impact evaluation and subsequent outcomes of EM&V/DPS negotiations, the 0.55 adjustment factor is intended to better align the savings estimated by HERO algorithms to those established by evaluation. Since the algorithms used by this characterization closely align with HERO, the same adjustment factor is adopted.

[5] Heating Degree Hours for attic assumes a base temperature of 58 degrees F and uses Climate Normals data for Burlington Internation Airport. A recent Nest study by EVT revealed that a base temperature of 58 degrees is appropriate to capture the heating tendencies of a typical Vermont home. See referenced document "NEST VEIC Data Share 9Jun2017." In an attempt to make a conservative estimate of heating degree hours, it was assumed that only days within a defined heating season would be included in the total, assuming that homeowners would disable or set back heating systems in the off season. The heating season was defined as the time period where temperatures "consistently" fall below 58 degrees. Based on visual inspection of TMY3 data, this period was established as September 19th to May 6th. Heating Degree Hours for basement assumes a blend of conditioned and unconditioned space as reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Unconditioned space HDH assumes a base temperature of 48 degrees F based on the premise that unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool. See worksheets "Foundation Blend" and "HDH - Climate Normals" in the HPwES 2.0 Support Workbook FINAL for a complete derivation.

[6] Based on program requirements, which align with Vermont RBES. The R-value for basements appears higher than what the program and RBES requires (R-15) due to the fact that the thermal resistance properties of soil have been accounted for in basements that are below grade. The final weighted number is a composite value based on statistics of homes with below, mixed and no basement (crawlspace) that have been sourced from the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. For a full derivation, see the worksheet "Foundation Blend" in the HPwES 2.0 Support Workbook FINAL.

[7] The final value for basements is a weighted, composite value based on statistics of homes with below, mixed and no basement (crawlspace). Additionally, it accounts for the thermal resistance properties of soil. For a full derivation, see the worksheet "Foundation Blend" in the HPwES 2.0 Support Workbook FINAL.

[8] EVT performed a sampling of 35 FY2020 projects. Contractors were interviewed and desk reviews of projects were completed to evaluate measure realization rates. Basement and attic insulation realization rate established by using TRM-based algorithms with verified variable inputs. For 2021, the attic realization rate is increased to 40% to reflect on-going improvements in documentation of projects. EVT will be actively working to update the shell TRMs for 2022.

[9] The average area for open attics is derived from a dataset of ~4,400 past EVT home performance projects. See worksheets "Additional Assumptions" and "Airsealing Improvement Factor" for a complete derivation. Basement treatment area (wall area) uses median reported floor areas in the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 (Table 12) as a basis and assumes completely square areas, eight foot wall heights for full basements and four foot wall heights for crawlspaces. Final value is a weighted, composite number based on foundation type and prevalence in the EVT market territory. For a full derivation, see the worksheet "Foundation Blend" in the HPwES 2.0 Support Workbook FINAL.

[10] Lifetimes consistent with Tracker assumptions.

[11] Due to highly variable scopes and approaches to insulating, EVT will use actual cost data collected for a particular performance year to perform a year-end adjustment to deemed costs to align with actual average costs.