

**DELAWARE
TECHNICAL REFERENCE MANUAL
VERSION 3.0**

~~April 2023~~ July 2024

Prepared by Optimal Energy

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INTRODUCTION

The Delaware Technical Reference Manual (TRM) is intended to document in detail common assumptions for significant prescriptive residential and commercial/industrial electric and gas energy efficiency measures savings. This document is largely based upon the Mid-Atlantic Technical Reference Manual, a technical assistance project of the Regional Evaluation, Measurement and Verification Forum (EM&V Forum) facilitated by Northeast Energy Efficiency Partnerships (NEEP). Until May 2019, the Delaware Department of Natural Resources and Environmental Control (DNREC) was a project sponsor of the Mid-Atlantic TRM. As such, this document uses Mid-Atlantic Technical Reference Manual Version 9 as a foundation and makes incremental changes to better reflect market conditions in Delaware and stakeholder priorities.¹

For each measure, the TRM includes either specific deemed values or algorithms² for calculating:

- Gross annual electric energy savings;
- Gross electric summer coincident peak demand savings;
- Gross annual fossil fuel energy savings (for electric efficiency measures that also save fossil fuels, and for certain measures that can save electricity or fossil fuels);
- Other resource savings if appropriate (e.g. water savings, O&M impacts);
- Incremental costs; and

¹ Shelter Analytics. 2019. *Mid-Atlantic Technical Reference Manual Version 9*. Prepared on behalf of Northeast Energy Efficiency Partnerships.
https://neep.org/sites/default/files/resources/Mid_Atlantic_TRM_V9_Final_clean_wUpdateSummary%20-%20CT%20FORMAT.pdf

² Typically, the algorithms provided contain a number of deemed underlying assumptions which when combined with some measure specific information (e.g. equipment capacity) produce deemed calculated savings values.

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The TRM is intended to be easy to use and to serve a wide range of important users and functions, including:

- **Utilities and efficiency Program Administrators** – for cost-effectiveness screening and program planning, tracking, and reporting.
- **Regulatory entities, independent program evaluators, and other parties** – for evaluating the performance of efficiency programs relative to statutory goals and facilitating planning and portfolio review; and
- **Markets, such as PJM’s Reliability Pricing Model (its wholesale capacity market) and future carbon markets** – for valuing efficiency resources.

Use of the TRM

As noted above, the TRM is intended to serve as an important tool to support rate-funded efficiency investments; for planning, implementation and assessment of success in meeting specific state goals. In addition, the TRM is intended to support the bidding of efficiency resources into capacity markets, such as PJM’s Reliability Pricing Model and in setting and tracking future environmental and climate change goals. It provides a common platform for the Delaware stakeholders to characterize measures within their efficiency programs, analyze and meaningfully compare cost-effectiveness of measures and programs, communicate with policymakers about program details, and it can guide future evaluation and measurement activity and help identify priorities for investment in further study, needed either at a regional or individual organizational level.

The savings estimates are expected to serve as representative, recommended values, or ways to calculate savings based on program-specific information. All information is

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presented on a per measure basis. In using the measure-specific information in the TRM, it is helpful to keep the following notes in mind:

- Additional information about the program design is sometimes included in the measure description because program design can affect savings and other parameters.
- Savings algorithms are typically provided for each measure. For a number of measures, prescriptive values for each of the variables in the algorithm are provided along with the output from the algorithm. That output is the deemed savings. For other measures, prescriptive values are provided for only some of the variables in the algorithm, with the term “actual” or “actual installed” provided for the others. In those cases – which one might call “deemed calculations” rather than “deemed savings” – users of the TRM are expected to use actual efficiency program data (e.g. capacities or rated efficiencies of central air conditioners) in the formula to compute savings. Note that the TRM typically provides *example calculations* for measures requiring “actual” values. These are for illustrative purposes only.
- All estimates of savings are annual savings and are assumed to be realized for each year of the measure life (unless otherwise noted).
- Unless otherwise noted, measure life is defined to be “the life of an energy consuming measure, including its equipment life and measure persistence (not savings persistence)” (EMV Forum Glossary). Conceptually it is similar to expected useful life, but the results are not necessarily derived from modeling studies, and many are from a report completed for New England program administrators’ and regulators’ State Program Working Group that is currently used to support the New England Forward Capacity Market M&V plans.

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- Where deemed values for savings are provided, these represent average savings that could be expected from the average measures that might be installed in the region during the current program year.
- For measures that are not weather-sensitive, peak savings are estimated whenever possible as the average of savings between 2 pm and 6 pm across all summer weekdays (i.e. PJM's EE Performance Hours for its Reliability Pricing Model). Where possible for cooling measures, we provide estimates of peak savings in two different ways. The primary way is to estimate peak savings during the most typical peak hour (assumed here to be 5 p.m.) on days during which system peak demand typically occurs (i.e., the hottest summer weekdays). This is most indicative of actual peak benefits. The secondary way – typically provided in a footnote – is to estimate peak savings as it is measured for non-cooling measures: the average between 2 pm and 6 pm across all summer weekdays (regardless of temperature). The second way is presented so that values can be bid into the PJM RPM.
- Wherever possible, savings estimates and assumptions are based on mid-Atlantic data. However, a number of assumptions – including assumptions regarding peak coincidence factors – are based on sources from other regions, often adjusted for climate or other known regional differences.
- While this information is not perfectly transferable, due to differences in definitions of peak periods as well as geography, climate and customer mix, it was used because it was the most transferable and usable source available at the time.³
- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and

³ For more discussion about the transferability of consumption data, see the EMV Forum Report: Cataloguing Available End-Use and Efficiency Measure Load Data, October 2009 at <http://neep.org/emv-forum/forum-products-and-guidelines>.

transparently, and they are widely accepted in the industry. Unlike simulation model results, they also provide flexibility and opportunity for users to substitute locally specific information and to update some or all parameters as they become available on an ad hoc basis. One limitation is that certain interactive effects between end uses, such as how reductions in waste heat from many efficiency measures impacts space conditioning, are not universally captured in this version of the TRM.⁴

- For some of the whole-building program designs that are being planned or implemented in Delaware, simulation modeling may be needed to estimate savings.
- In general, the baselines included in the TRM are intended to represent average conditions in the Mid-Atlantic. Some are based on data from the Mid-Atlantic, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Mid-Atlantic data are not available. Some are based on code.
- The TRM anticipates the effects of changes in efficiency standards for measures as appropriate, specifically lighting and motors.

The following table outlines the terms used to describe the assumed baseline conditions for each measure. The third portion of each measure code for each measure described in this TRM includes the abbreviation of the program type for which the characterization is intended:

⁴ They are captured for lighting and some motor-related measures.

Baseline Condition	Attributes
Time of Sale (TOS)	Definition: A program in which the customer is incented to purchase or install higher efficiency equipment than if the program had not existed. This may include retail rebate (coupon) programs, upstream buydown programs, online store programs, contractor based programs, or CFL giveaways as examples. May include replacement or existing equipment at the end of its life (i.e., replace on burnout), or purchase of new equipment. In cases where a new construction characterization isn't explicitly provided, the TOS characterization is typically appropriate. Baseline = New standard efficiency or code compliant equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Appliance rebate
New Construction (NC)	Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices. Baseline = Building code or federal standards. Efficient Case = The program's level of building specification Example: Building shell and mechanical measures
Retrofit (RF)	Definition: A program that <i>upgrades</i> 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 = Post-retrofit efficiency of equipment. Example: Air sealing, insulation, and controls.
Early Replacement (EREP)	Definition: A program that <i>replaces</i> existing, operational equipment.⁵ Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the remaining life of the existing equipment is over.

⁵ The criteria that are used to determine whether equipment is "operational" vary among jurisdictions and there is no related industry standard practice. This TRM provides assumptions for estimating savings and costs for early replacement measures, but does not address this threshold question of whether a measure should be considered early replacement.

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Baseline Condition	Attributes
	<u>Efficient Case</u> = New, premium efficiency equipment above federal and state codes and standard industry practice. <u>Example</u> : Refrigerators and freezers.
Early Retirement (ERET)	<u>Definition</u> : A program that <i>retires</i> inefficient, operational duplicative equipment or inefficient equipment that might otherwise be resold. <u>Baseline</u> = The existing equipment, which is retired and not replaced. <u>Efficient Case</u> = Assumes zero consumption since the unit is retired. <u>Example</u> : Appliance recycling.
Direct Install (DI)	<u>Definition</u> : A program where measures are installed during a site visit. <u>Baseline</u> = Existing equipment. <u>Efficient Case</u> = New, premium efficiency equipment above federal and state codes and standard industry practice. <u>Example</u> : Lighting and low-flow hot water measures

Measure Cost Development and Use

Measure costs are calculated differently depending upon the program type, discussed above, used to promote a given measure. These calculations are summarized below.

Time of Sale and New Construction Incremental Costs

Calculations of Time of Sale and New Construction incremental costs in the Delaware TRM are generally the difference between the measure equipment and labor costs and the baseline equipment and labor costs. In most cases, the measure and baseline labor costs are equal and so the time of sale incremental cost is simply the difference between the baseline and measure equipment costs. In general, no discounting of future costs is needed since all costs are incurred at the time of project installation.

Retrofit and Full Costs

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Retrofit measure incremental costs and full costs are equal to the total measure costs. Generally, no discounting of future costs is needed since all costs are incurred at the time of project installation. Retrofit measures generally comprise efficiency enhancement such as building shell measures, HVAC tune ups, etc. Full cost values may be needed to estimate program costs for programs that pay all or a percentage of project costs.

Early Replacement Incremental Costs

Calculation of early replacement incremental costs in the Delaware TRM includes two components:

1. The discounted future costs that would have been incurred when the replaced equipment would have needed to be replaced had it not been replaced early needs to be subtracted from the initial measure costs; and
2. The present value costs associated with purchasing the high efficiency equipment today while the existing equipment is still operational.

The calculations are provided in Itron, Mid-Atlantic TRM Version 7.5 Incremental Costs Update, 2017 at:

<http://www.neep.org/initiatives/emv-forum/forum-products>

The methods and rationale are discussed in Evergreen Economics, Michaels Energy and Phil Wilhems, Early Replacement Measures Study Final Phase II Research Report, November 4, 2015 for the Evaluation, Measurement and Verification Forum facilitated by Northeast Energy Efficiency Partnerships, pp. 36-45. See

<http://www.neep.org/sites/default/files/resources/FINAL%20NEEP%20Report.pdf>.

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TRM Update History

Version	Issued
1.0	April 2021
2.0	April 2023

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RESIDENTIAL MARKET SECTOR

Lighting End Use

Solid State Lighting (LED) Recessed Downlight Luminaire

Unique Measure Code: RS_LT_TOS_SSLEDWN_0415, RS_LT_EREP_SSLEDWN_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight luminaire in place of an incandescent downlight lamp/luminaire (i.e. time of sale). The SSL downlight should meet the ENERGY STAR Luminaires Version 2.0-12 specification⁶. The characterization of this measure should not be applied to other types of LEDs.

Note, this measure assumes the baseline is a Bulged Reflector (BR) lamp. This lamp type is generally the cheapest and holds by far the largest market share for this fixture type.

The measure provides assumptions for two markets (Residential and Multi-Family).

⁶ ENERGY STAR specification can be viewed here:

<https://www.energystar.gov/sites/default/files/Luminaires%20V2.2%20Final%20Specification.pdf>
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification_1.pdf
<https://www.energystar.gov/sites/default/files/asset/document/Luminaires%20V2%200%20Final.pdf>

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Definition of Baseline Condition

The baseline is the purchase and installation of a lamp meeting the EISA 2007 efficacy backstop with light output similar to a standard BR30-type incandescent downlight light bulb. See the “Baseline Adjustment” section below for additional discussion.

Definition of Efficient Condition

The efficient condition is the purchase and installation of an ENERGY STAR Solid State Lighting (LED) Recessed Downlight luminaire.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) / 1,000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} - 1))$$

Where:

WattsBase = Connected load of baseline lamp
= Based on lumens of the LED – find the equivalent baseline wattage from the table below. If unknown assume 23W. ⁷
See the “Baseline Adjustment” section below for additional discussion.⁸

⁷ Baseline wattage based on 45 lm/W efficacy and typical light output of common 65 Watt BR30 incandescent bulb (e.g. <http://www.destinationlighting.com/storeitem.jhtml?iid=16926>)
⁸ See ‘Mid-Atlantic TRM V7.5 ESTAR SSL Lumen Equivalence.xlsx’ for details. The Minimum Lamp Efficacy Requirements in ENERGY STAR Product Specification for Lamps (Light Bulbs) V2.0 vary by Color Rendering Index (CRI).

Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
400	449	9
450	499	10
500	649	14
650	1419	23

WattsEE = Connected load of efficient lamp
 = Actual. If unknown assume 9.2W⁹
ISR = In Service Rate or percentage of units rebated that get installed.
 = 1.0¹⁰
HOURS = Average hours of use per year

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.86	679 ¹¹
Multi Family Common Areas	16.3	5,950 ¹²

⁹ Energy efficient wattage based on 12 Watt LR6 Downlight from LLF Inc. Adjusted by ratio of lm/W in ENERGY STAR V2.0 compared to ENERGY STAR V1.2 specification.

¹⁰ Based upon recommendation in NEEP EMV Emerging Tech Research Report.

¹¹ Based on Navigant Consulting, "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 13. This assumption is a product of metered CFLs and LEDs. To date there has not been sufficient data available to provide a separate LED hours assumption, and this should be reviewed in future years.

¹² Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. This estimate is consistent with the Common Area "Non-Area Specific" assumption (16.2 hours per day or 5913 annually) from the Cadmus Group Inc., "Massachusetts Multifamily Program Impact Analysis", July 2012, p 2-4.

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Installation Location	Daily Hours	Annual Hours
Unknown	1.86	679

WHFeCool = Waste Heat Factor for Energy to account for cooling savings from reducing waste heat from efficient lighting.

	WHFeCool
Building with cooling	1.087 ¹³
Building without cooling or exterior	1.0
Unknown	1.077 ¹⁴

WHFeHeat = Waste Heat Factor for Energy to account for electric heating savings from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.899¹⁵

¹³ The value is estimated at 1.087 (calculated as 1 + (0.33 / 3.8)). Based on cooling loads decreasing by 33% of the lighting savings (average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC), assuming typical cooling system operating efficiency of 3.8 COP (from the current federal minimum of 13 SEER) , converted to COP = SEER/3.412 = 3.8COP).

¹⁴ The value is estimated at 1.077 (calculated as 1 + (0.89*(0.33 / 3.8)). Based on assumption that 89% of homes have central cooling (based on KEMA Maryland Energy Baseline Study. Feb 2011.).

¹⁵ Calculated using defaults; 1+ ((0.47/1.74) * 0.375) = 0.899

HF = Heating Factor or percentage of light savings that must be heated
= 47%¹⁶ for interior or unknown location
= 0% for exterior or unheated location

ηHeat = Efficiency in COP of Heating equipment
= actual. If not available, use¹⁷:

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.74 ¹⁸

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%

¹⁶ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

¹⁷ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

¹⁸ Calculation assumes 59% Heat Pump and 41% Resistance which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey. Average efficiency of heat pump is based on assumption 50% are units from before 2006 and 50% after.

Unknown	37.5% ¹⁹

Illustrative example – do not use as default assumption
Residential interior and in-unit Multi Family

$$\Delta kWh = ((23 - 9.2) / 1,000) * 1.0 * 679 * (0.899 + (1.077 - 1))$$

= 9.1 kWh

Multi Family Common Areas

$$\Delta kWh = ((23 - 9.2) / 1,000) * 1.0 * 5950 * (0.899 + (1.077 - 1))$$

= 80.1 kWh

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF$$

¹⁹ Based on KEMA baseline study for Maryland.

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting

	WHFd
Building with cooling	1.19 ²⁰
Building without cooling	1.0
Unknown	1.17 ²¹

CF = Summer Peak Coincidence Factor for measure

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.059 ²²
	PJM CF	0.058 ²³
Multi Family Common Areas	PJM CF	0.86 ²⁴
Unknown	Utility Peak CF	0.059
	PJM CF	0.058

Illustrative example – do not use as default assumption

$\Delta kW_{PJM} = ((23 - 9.2) / 1,000) * 1.0 * 1.17 * 0.058$

²⁰ The value is estimated at 1.19 (calculated as 1 + (0.66 / 3.8)). See footnote relating to WHFe for details. Note the 66% factor represents the Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load (i.e. consistent with the PJM coincident definition).

²¹ The value is estimated at 1.17 (calculated as 1 + (0.89 * 0.66 / 3.52)).

²² Based on Navigant Consulting “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 15.

²³ Ibid.

²⁴ Consistent with value currently used for EmPOWER Maryland Programs as of October 1, 2017. Derived from C&I common area lighting coincidence.

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= 0.0009 kW

Annual Fossil Fuel Savings Algorithm

Heating Penalty if Fossil Fuel heated home (if heating fuel is unknown assume 62.5% of homes heated with fossil fuel):

$$\Delta\text{MMBTUPenalty}^{25} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF} * 0.003412) / \eta\text{Heat} * \%FossilHeat$$

Where:

- HF = Heating Factor or percentage of light savings that must be heated
 - = 47%²⁶ for interior or unknown location
 - = 0% for exterior or unheated location
- 0.003412 = Converts kWh to MMBTU
- ηHeat = Efficiency of heating system
 - = 80%²⁷
- %FossilHeat = Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%

²⁵ Negative value because this is an increase in heating consumption due to the efficient lighting.

²⁶ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

²⁷ U.S. Code of Federal Regulations at 10 CFR 430.32(e).

Fossil Fuel	100%
Unknown	62.5% ²⁸

Illustrative example – do not use as default assumption

A luminaire in a home with 75% AFUE gas furnace:

ΔMMBTUPenalty

= - (((23 – 9.2)/1000) * 1.0 * 679 * 0.47 * 0.003412/0.75) * 1.0

= - 0.02 MMBTU

If home heating fuel is unknown:

ΔMMBTUPenalty

= - (((23 – 9.2)/1000) * 1.0 * 679 * 0.47 * 0.003412/0.80) * 0.625

= - 0.01 MMBTU

Annual Water Savings Algorithm

n/a

Incremental Cost

²⁸ Based on KEMA baseline study for Maryland.

The lifecycle NPV incremental cost for time of sale replacements is \$1.35, based on a baseline incandescent BR lamp cost of \$3.57 and an LED BR Lamp cost of \$4.92.²⁹ Early replacements should use the full installed cost of \$4.92.

Measure Life

The measure life is assumed to be 20 yrs for Residential and Multi Family in-unit, and 8.4 years for Multi Family common areas for downlights featuring inseparable components, and 4.2 years for downlights with replaceable parts.³⁰

Operation and Maintenance Impacts

The levelized baseline replacement cost over the lifetime of the SSL is calculated (see MidAtlantic Lighting adjustments and O&M_042015.xls). The key assumptions used in this calculation are documented below:

	BR-type Incandescent
Replacement Cost	\$3.57

²⁹ Cost assumptions are adapted from 2018 data provided by Lighttracker Inc. The information from Lighttracker is based in part on data reported by IRI through its Advantage service for, and as interpreted solely by, Lighttracker Inc. IRI disclaims liability of any kind arising from the use of this information. The information from Lighttracker is also based in part on data from Nielsen through its Strategic Planner and Homescan Services for the lighting category for the 52-week period ending approximately on December 31, 2018, for the Maryland and U.S. markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2018, Nielsen.

³⁰ The ENERGY STAR Spec for SSL Recessed Downlights requires luminaires to maintain >=70% initial light output for 25,000 hours in an indoor application for separable luminaires and 50,000 for inseparable luminaires. Measure life is capped at 20 years.

	BR-type Incandescent
Component Life ³¹ (years)	2.95 ³²
Residential interior and in-unit Multi Family or unknown.	
Multi Family Common Areas	0.34 ³³

The calculated net present value of the baseline replacement costs is \$0.00 for Residential interior and in-unit Multi Family \$10.12 for downlights installed in Multifamily common areas.

Baseline Adjustment

The Energy Independence and Security Act (EISA) of 2007 included an efficacy “backstop” requiring that all general service lamps sold meet or exceed an efficacy requirement of 45 lumens per watt by 1/1/2020. Further, the definition of general service lamps was broadened by two Final Rules published by the DOE on 1/19/2017 to effectively cover all common lamp types.³⁴ In December 2019, the DOE retracted the definition expansion and effectively eliminated the efficacy backstop.³⁵ Regulatory uncertainty persists in that the new rule faces significant legal challenges³⁶ and the

³¹ Based on lamp life / assumed annual run hours.

³² Assumes rated life of BR incandescent bulb of 2000 hours, based on product review. Lamp life is therefore $2000/679 = 2.95$ years.

³³ Calculated as $2000/5950 = 0.34$ years.

³⁴ Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7276 (January 19, 2017) (to be codified at 10 CFR Part 430) and Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7322 (January 19, 2017) (to be codified at 10 CFR Part 430).

³⁵ <https://www.regulations.gov/document/EERE-2018-BT-STD-0010-0450>

³⁶ <https://thehill.com/policy/energy-environment/484559-energy-department-sued-over-lightbulb-efficiency-rollback>

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current federal administration has signaled it's intent to revisit the issue. Given this volatility and the fact that market transformation in lighting is already well underway, this measure establishes baselines consistent with the broadened GSL definition and EISA efficacy backstop to better reflect true market conditions.

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ENERGY STAR Integrated Screw Based SSL (LED) Lamp

Unique Measure Code: RS_LT_TOS_SSLEDWN_0619, RS_LT_EREP_SSLEDWN_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp in place of an incandescent lamp.

The measure provides assumptions for two markets (Residential and Multi-Family).

Definition of Baseline Condition

For time of sale, the baseline wattage is assumed to be an incandescent or EISA compliant (where applicable) bulb installed in a screw-base socket³⁷. Note that the baseline will be EISA compliant bulbs for all categories to which EISA applies. If the in-situ lamp wattage is known and lower than the EISA mandated maximum wattage (where applicable), the baseline wattage should be assumed equal to the in situ lamp wattage.

Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. The ENERGY STAR V2.0-1 specifications can be viewed here:

³⁷ For text of Energy and Independence and Security Act, see <http://www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf>

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<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf>

Annual Energy Savings Algorithm

For all lamps EXCEPT: PAR, MR and MRX
 $\Delta kWh = ((WattsBase - WattsEE) / 1000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} - 1))$
Where:
WattsBase = Based on lumens of the LED – find the equivalent baseline wattage from the table below. The table also shows the baseline shift from the EISA backstop taking effect in 2020. See the “Baseline Adjustment” section below for additional discussion.³⁸

	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
Omnidirectional, Medium Screw Base Lamps (A, BT, P, PS, S or T) (†, ‡see exceptions below)	250	309	25
	310	749	12
	750	1049	20
	1050	1489	28
	1490	2600	46
	2601	3300	66
	3301	3999	200
	4000	6000	300
†S Shape <=749 lumens and T Shape	250	309	25

³⁸ See ‘Mid-Atlantic TRM V7.5 ESTAR SSL Lumen Equivalence.xlsx’ for details. The Minimum Lamp Efficacy Requirements in ENERGY STAR Product Specification for Lamps (Light Bulbs) V2.0 vary by Color Rendering Index (CRI).

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
<=749 lumens or T>10" length)	310	749	12
Decorative, Medium Screw Base (G Shape) (‡see exceptions below)	250	309	25
	310	749	12
	750	1049	20
	1050	1300	26
‡G16-1/2, G25, G30 <=499 lumens	250	309	25
	310	349	7
	350	499	9
‡G Shape with diameter >=5"	250	349	25
	350	499	40
	500	574	60
	575	649	75
	650	1099	100
	1100	1300	150
Decorative, Medium Screw Base (B, BA, C, CA, DC, and F, and ST) (*see exceptions below)	70	89	10
	90	149	15
	150	299	25
	300	309	40
	310	499	9
	500	699	13
*B, BA, CA, and F <=499 lumens	70	89	10
	90	149	15
	150	299	25

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
	300	309	40
	310	499	9
Omnidirectional, Intermediate Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	25
	310	749	12
†S Shape that have a first number symbol <= 12.5 and T Shape lamps with first number symbol <= 8 and nominal overall length <12"	250	309	25
	310	749	40
Decorative, Intermediate Screw Base (G Shape) (‡see exceptions below)	250	309	25
	310	349	7
	350	499	9
‡G Shape with first numeral less than 12.5 or with diameter >=5"	250	349	25
	350	499	40
Decorative, Intermediate Screw Base (B, BA, C, CA, DC, and F, and ST)	70	89	10
	90	149	15
	150	299	25
	300	309	40
	310	499	9
	250	309	25

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
Omnidirectional, Candelabra Screw Base Lamps (A, BT, P, PS, S or T) (*see exceptions below)	310	749	12
	750	1049	20
†S Shape that have a first number symbol <= 12.5 and T Shape with first number symbol <= 8 and nominal overall length <12"	250	309	25
	310	749	40
	750	1049	60
Decorative, Candelabra Screw Base (G Shape) (§see exceptions below)	250	309	25
	310	349	7
	350	499	9
	500	574	12
‡G Shape with first numeral less than 12.5 or with diameter >=5"	250	349	25
	350	499	40
	500	574	60
Decorative, Candelabra Screw Base (B, BA, C, CA, DC, and F, and ST)	70	89	10
	90	149	15
	150	299	25
	300	309	40
	310	499	9
	500	699	13
	400	449	9
	450	499	10

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
Directional, Medium Screw Base, w/diameter <=2.25"	500	649	13
	650	1199	20
Directional, Medium Screw Base, R, , ER, BR, BPAR or similar bulb shapes w/ diameter >2.5 " (**see exceptions below)	640	739	15
	740	849	18
	850	1179	22
	1180	1419	29
	1420	1789	36
	1790	2049	43
	2050	2579	51
	2580	3300	65
	3301	3429	120
	3430	4270	150
Directional, Medium Screw Base, R, , ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26" and ≤ 2.5" (**see exceptions below)	540	629	13
	630	719	15
	720	999	19
	1000	1199	24
	1200	1519	30
	1520	1729	36
	1730	2189	44
	2190	2899	56
	2900	3300	69
	3301	3850	150
**ER30, BR30, BR40, or ER40	400	449	9
	450	499	10

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
	500	649-1179	14
**BR30, BR40, or ER40	650	1419	23
**R20	400	449	9
	450	719	13
**All reflector lamps below lumen ranges specified above	200	299	20
	300	399-639	9
ØRough service, shatter resistant, 3- way incandescent, and vibration service	250	309	25
	310	749	12
	750	1049	20
	1050	1489	28
	1490	2600	46
	2601	3300	66
	3301	3999	200
	4000	6000	300

WattsBase for PAR, MR, and MRX Lamp Types:

For highly focused directional lamps, Center Beam Candle Power (CBCP) and beam angle measurements are needed for accurate estimate of the equivalent baseline wattage. Use the Energy Star Center Beam Candle Power tool³⁹ to verify the lamp meets minimum lumen requirements for the claimed base equivalent Watts. If CBCP and

³⁹ <https://www.energystar.gov/sites/default/files/ESLampCenterBeamTool%20rev%202016-09-01.xlsx>

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beam angle information are not available or if the equation below returns a negative value (or undefined), use the manufacturer’s recommended baseline wattage equivalent.⁴⁰ See the Energy Star Center Beam Candle Power tool here: <https://www.energystar.gov/sites/default/files/ESLampCenterBeamTool%20rev%202016-09-01.xlsx>

The result of the Energy Star calculator or equation above should be rounded DOWN to the nearest wattage established by Energy Star: ⁴¹

Diameter	Permitted Wattages
16	20, 35, 40, 45, 50, 60, 75
20	50
30S	40, 45, 50, 60, 75
30L	50, 75
38	40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250

WattsEE

ISR

HOURS

= Actual LED wattage

= In Service Rate or percentage of units rebated that get installed.

= 0.98⁴²

= Average hours of use per year

⁴⁰ The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations - specifically for lamps with very high CBCP.

⁴¹ Ibid.

⁴² First year ISR of 0.9 (EMPOWER MD Lighting Study, EY5). Assume lifetime ISR of 0.99 (2006-2008 California Residential Lighting Evaluations, and used in the Uniform Methods Project). Assume half of bulbs not installed in year one are installed in year two, and the other half in year three. Using a discount rate of 5%, this gives $0.90 + 0.045 * 0.95 + 0.045 * 0.95^2 = 0.98$

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Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.86	679 ⁴³
Multi Family Common Areas	16.3	5,950 ⁴⁴
Exterior	4.5	1,643 ⁴⁵
Unknown	1.86	679 ⁴⁶

WHFe_{Cool} = Waste Heat Factor for Energy to account for cooling savings from reducing waste heat from efficient lighting.

	WHFe _{Cool}
Building with cooling	1.087 ⁴⁷

⁴³ Based on Navigant Consulting, “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 13. This assumption is a product of metered CFLs and LEDs. To date there has not been sufficient data available to provide a separate LED hours assumption, and this should be reviewed in future years.

⁴⁴ Multi family common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. This estimate is consistent with the Common Area “Non-Area Specific” assumption (16.2 hours per day or 5913 annually) from the Cadmus Group Inc., “Massachusetts Multifamily Program Impact Analysis”, July 2012, p 2-4.

⁴⁵ Updated results from Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004, presented in 2005 memo; http://publicservice.vermont.gov/energy/ee_files/efficiency/eval/marivtfinalresultsmemodelivered.pdf

⁴⁶ “Unknown” assumes a residential interior or in-unit multifamily application.

⁴⁷ The value is estimated at 1.087 (calculated as $1 + (0.33 / 3.8)$). Based on cooling loads decreasing by 33% of the lighting savings (average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC),

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Building without cooling or exterior	1.0
Unknown	1.077 ⁴⁸

WHFe_{Heat} = Waste Heat Factor for Energy to account for electric heating savings from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 - ((HF / η Heat) * %ElecHeat). If unknown assume 0.899⁴⁹

HF = Heating Factor or percentage of light savings that must be heated
= 47%⁵⁰ for interior or unknown location
= 0% for exterior or unheated location

η Heat = Efficiency in COP of Heating equipment
= actual. If not available, use⁵¹:

assuming typical cooling system operating efficiency of 3.8 COP (from the current federal minimum of 13 SEER), converted to COP = SEER/3.412 = 3.8 COP).

⁴⁸ The value is estimated at 1.077 (calculated as 1 + (0.89*(0.33 / 3.8)). Based on assumption that 89% of homes have central cooling (based on KEMA Maryland Energy Baseline Study. Feb 2011.).

⁴⁹ Calculated using defaults; 1 + ((0.47/1.74) * 0.375) = 0.899

⁵⁰ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

⁵¹ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.74 ⁵²

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5% ⁵³

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" is installed in a residential interior location.

$$\Delta kWh = ((13 - 10) / 1,000) * 0.98 * 679 * (0.899 + (1.077 - 1))$$
$$= 1.9 kWh$$

⁵² Calculation assumes 59% Heat Pump and 41% Resistance which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey. Assume heat pump baseline of 7.7 HSPF.

⁵³ Based on KEMA baseline study for Maryland.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = ((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting

	WHFd
Building with cooling	1.19 ⁵⁴
Building without cooling or exterior	1.0
Unknown	1.17 ⁵⁵

CF = Summer Peak Coincidence Factor for measure

Installation Location	Type	Coincidence Factor (CF)
Residential interior and in-unit Multi Family	Utility Peak CF	0.059 ⁵⁶
	PJM CF	0.058 ⁵⁷
Multi Family Common Areas	PJM CF	0.86 ⁵⁸

⁵⁴ The value is estimated at 1.19 (calculated as 1 + (0.66 / 3.8)). See footnote relating to WHFe for details. Note the 66% factor represents the Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load (i.e. consistent with the PJM coincident definition).

⁵⁵ The value is estimated at 1.18 (calculated as 1 + (0.89 * 0.66 / 3.8)).

⁵⁶ Based on Navigant Consulting “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 15

⁵⁷ Ibid.

⁵⁸ Consistent with value currently used for EmPOWER Maryland Programs as of October 1, 2017. Derived from C&I common area lighting coincidence.

Installation Location	Type	Coincidence Factor (CF)
Exterior	PJM CF	0.018 ⁵⁹
Unknown	Utility Peak CF	0.059
	PJM CF	0.058

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" is installed in a residential interior location.

$$\Delta kW_{PJM} = ((13 - 10) / 1,000) * 0.98 * 1.17 * 0.058$$
$$= 0.0002 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Heating Penalty if Fossil Fuel heated home (if heating fuel is unknown assume 62.5% of homes heated with fossil fuel):

$$\Delta \text{MMBTUPenalty} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF} * 0.003412) / \eta_{\text{Heat}} * \% \text{FossilHeat}$$

Where:

HF

= Heating Factor or percentage of light savings that must be heated

⁵⁹ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

0.003412

 η_{Heat}

%FossilHeat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5% ⁶²

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter ≤ 2.25 " is installed in a residential interior location with unknown heating fuel.

$$\Delta \text{MMBTUPenalty} = - ((13 - 10) / 1,000) * 0.98 * 679 * 0.47 * 0.003412 / 0.80 * 0.625$$
$$= - 0.003 \text{ MMBTU}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

⁶⁰ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

⁶¹ U.S. Code of Federal Regulations at 10 CFR 430.32(e).

⁶² Based on KEMA baseline study for Maryland.

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If the implementation strategy allows the collection of actual costs, or an appropriate average, then that should be used. If not, the lifecycle NPV incremental costs for time of sale replacements are provided below.⁶³

Category	Time of Sale Incremental Cost
Unknown	\$1.95
Globe	\$2.76
Reflector	\$0.69
A Lamp	\$1.57
Candelabra	\$3.37

Measure Life

The tables below show the assumed measure life for ENERGY STAR Version 2.0.

	Measure Life, Energy Star V2.0				
	Rated Life ⁶⁴	Residential interior, in-unit Multi Family or unknown	Multi Family Common Areas	Exterior	Unknown
Omnidirectional	15,000	20	2.52	9.1	13.6
Decorative	15,000	20	2.52	9.1	13.6
Directional	15,000 ⁶⁵	20	2.52	9.1	13.6

⁶³ Adapted from analysis provided by Apex Analytics LLC in April 2018.
⁶⁴ The ENERGY STAR Spec v2.0 for Integrated Screw Based SSL bulbs requires lamps to maintain >=70% initial light output for 15,000 hrs. Lifetime capped at 20 years.
⁶⁵ ENERGY STAR V2.1 specifications reduce rated life requirements to 15,000 hours for directional lamps.

Operation and Maintenance Impacts

To account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the LED is calculated (see ‘ESTAR Integrated Screw SSL Lamp_042817.xls’). The key assumptions used in this calculation are documented below:

	EISA 2020 Compliant
Replacement Cost Unknown	\$1.67
Replacement Cost, Globe	\$6.18
Replacement Cost, Reflector	\$1.99
Replacement Cost, A Lamp	\$3.10
Replacement Cost, Candelabra	\$3.45
Component Life (hours)	2,000

The calculation results in the following assumptions of equivalent annual baseline replacement cost:

Bulb Type	Indoor	Multi-Family Common area	Exterior
Unknown	\$1.33	\$13.76	\$10.13
Globe	\$1.14	\$18.37	\$13.52
Reflector	\$2.43	\$21.26	\$15.65
A Lamp	\$1.05	\$9.23	\$6.80
Candelabra	\$0.71	\$6.18	\$4.55

Baseline Adjustment

The Energy Independence and Security Act (EISA) of 2007 included an efficacy “backstop” requiring that all general service lamps sold meet or exceed an efficacy

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requirement of 45 lumens per watt by 1/1/2020. Further, the definition of general service lamps was broadened by two Final Rules published by the DOE on 1/19/2017 to effectively cover all common lamp types.⁶⁶ In December 2019, the DOE retracted the definition expansion and effectively eliminated the efficacy backstop.⁶⁷ Regulatory uncertainty persists in that the new rule faces significant legal challenges⁶⁸ and the current federal administration has signaled it's intent to revisit the issue. Given this volatility and the fact that market transformation in lighting is already well underway, this measure establishes baselines consistent with the broadened GSL definition and EISA efficacy backstop to better reflect true market conditions.

⁶⁶ Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7276 (January 19, 2017) (to be codified at 10 CFR Part 430) and Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7322 (January 19, 2017) (to be codified at 10 CFR Part 430).

⁶⁷ <https://www.regulations.gov/document/EERE-2018-BT-STD-0010-0450>

⁶⁸ <https://thehill.com/policy/energy-environment/484559-energy-department-sued-over-lightbulb-efficiency-rollback>

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Occupancy Sensor – Wall-Mounted

Unique Measure Code(s): RS_LT_RF_OSWALL_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure defines the savings associated with installing a wall-mounted occupancy sensor that switches lights off after a brief delay when it does not detect occupancy.

Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

Definition of Efficient Condition

The efficient condition is lighting that is controlled with an occupancy sensor. It is assumed that the controlled load is a mix of efficient and inefficient lighting.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_{connected} * HOURS * SVG_e * ISR * (WHF_{eHeat} + (WHF_{eCool} - 1))$$

Where:

kW_{connected} = Actual kW lighting load connected to control for direct install measures or other situations where the connected load is known. If *kW_{connected}* is not known, then use the following default assumptions.

Number of lamps in space with control	Average lamp wattage (B)	kW _{connected} (AxB)

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(A)		
6.8 ⁶⁹	0.034 ⁷⁰	0.230

HOURS = Average hours of use per day. If space type is known, then use average of efficient and inefficient hours of use below⁷¹:

Lamp Type	Average HOU of Efficient and Inefficient Lamps
Attic	0.4
Basement	2.6
Bathroom	1.3
Bedroom	1.3
Closet	0.3
Crawl Space	1.1
Dining Room	1.6
Exterior	1.3
Garage	0.9
Hall	1.4
Kitchen	3.5
Laundry	1.4

⁶⁹ Connecticut LED Lighting Study Report (R154). NMR Group, Inc. January 28, 2016. Average of number of sockets in dining room, living space, bedroom, bathroom, and kitchen spaces.

⁷⁰ Connecticut LED Lighting Study Report (R154). Average connected wattage of lamps in dining room, living space, bedroom, bathroom, and kitchen spaces

⁷¹ Based on Navigant Consulting, “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 14.

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Living Room	1.9
Mechanical	0.2
Office	3.2
Other	0.9

If space type is not known, then assume:

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.66 ⁷²	604 ⁷³
Multi Family Common Areas	16.3	5,950 ⁷⁴
Unknown	1.66 ⁷⁵	604 ⁷⁶

SVGe = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.

⁷² Based on Navigant Consulting, “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 13. This assumption is an average of the hours of use for efficient lamps (CFLs and LEDs at 679 hrs./yr.) and inefficient lamps (529 hrs./yr.).

⁷³ Based on Navigant Consulting, “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 13. This assumption is an average of the hours of use for efficient lamps (CFLs and LEDs at 679 hrs./yr.) and inefficient lamps (529 hrs./yr.).

⁷⁴ Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. This estimate is consistent with the Common Area “Non-Area Specific” assumption (16.2 hours per day or 5913 annually) from the Cadmus Group Inc., “Massachusetts Multifamily Program Impact Analysis”, July 2012, p 2-4. <http://ma-eeac.org/wordpress/wp-content/uploads/Massachusetts-Multifamily-Program-Impact-Analysis-Report-Appendix.pdf>

⁷⁵ “Unknown” assumes a residential interior or in-unit multifamily application.

⁷⁶ “Unknown” assumes a residential interior or in-unit multifamily application.

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ISR = 30%⁷⁷
= In Service Rate or percentage of units rebated that get installed
= 1.00⁷⁸

WHF_{Heat} = Waste Heat Factor for Energy to account for electric heating savings from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

= 1 - ((HF / η Heat) * %ElecHeat)

If unknown assume 0.899⁷⁹

HF = Heating Factor or percentage of light savings that must be heated
= 47%⁸⁰ for interior or unknown location
= 0% for exterior or unheated location

η Heat = Efficiency in COP of Heating equipment

⁷⁷ Cadmus Group Inc., “Massachusetts Multifamily Program Impact Analysis”, July 2012. Appendix A. 6-1. The study notes that this value is informed by commercial occupancy sensor applications. This value is cited in the Massachusetts 2016-2018 Plan Technical Reference Manual.

⁷⁸ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

⁷⁹ Calculated using defaults; 1 + ((0.47/1.74) * 0.375) = 0.899

⁸⁰ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

= actual. If not available, use⁸¹:

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.74 ⁸²

$\% \text{ElecHeat}$ = Percentage of homes with electric heat

Heating fuel	$\% \text{ElecHeat}$
Electric	100%
Fossil Fuel	0%
Unknown	37.5% ⁸³

$\text{WHFe}_{\text{Cool}}$ = Waste Heat Factor for Energy to account for cooling savings from reducing waste heat from efficient lighting.

$\text{WHFe}_{\text{Cool}}$

⁸¹ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and again in 2015 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

⁸² Calculation assumes 59% Heat Pump and 41% Resistance which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey. Assume heat pump baseline of 7.7 HSPF.

⁸³ Based on KEMA Maryland Energy Baseline Study. Feb 2011

Building with cooling	1.087 ⁸⁴
Building without cooling or exterior	1.0
Unknown	1.077 ⁸⁵

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kW_{\text{connected}} * SVGd * ISR * WHFd * CF$$

Where:

SVGd = Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.
= 30%⁸⁶

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting

	WHFd
Building with cooling	1.19 ⁸⁷

⁸⁴ The value is estimated at 1.087 (calculated as $1 + (0.33 / 3.8)$). Based on cooling loads decreasing by 33% of the lighting savings (average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC), assuming typical cooling system operating efficiency of 3.8 COP (from the current federal minimum of 13 SEER), converted to $COP = SEER / 3.412 = 3.8$ COP).

⁸⁵ The value is estimated at 1.077 (calculated as $1 + (0.89 * (0.33 / 3.8))$). Based on assumption that 89% of homes have central cooling (based on KEMA Maryland Energy Baseline Study, Feb 2011.).

⁸⁶ Assumed to be the same as the energy savings percentage (SVGe).

⁸⁷ The value is estimated at 1.19 (calculated as $1 + (0.66 / 3.8)$). See footnote relating to WHFe for details. Note the 66% factor represents the Residential cooling coincidence factor

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Building without cooling or exterior	1.0
Unknown	1.17 ⁸⁸

CF = Summer Peak Coincidence Factor for measure

Installation Location	Type	Coincidence Factor (CF)
Residential interior and in-unit Multi Family	Utility Peak CF	0.059 ⁸⁹
	PJM CF	0.058 ⁹⁰
Multi Family Common Areas	PJM CF	0.86 ⁹¹
Exterior	PJM CF	0.018 ⁹²
Unknown	Utility Peak CF	0.059
	PJM CF	0.058

Annual Fossil Fuel Savings Algorithm

Heating Penalty if Fossil Fuel heated home (if heating fuel is unknown assume 62.5% of homes heated with fossil fuel):

$$\Delta\text{MMBTUPenalty} = \text{kWconnected} * \text{HOURS} * \text{SVGe} * \text{ISR} * \text{HF} * 0.003412 /$$

calculated by dividing average load during the peak hours divided by the maximum cooling load (i.e. consistent with the PJM coincident definition).

⁸⁸ The value is estimated at 1.18 (calculated as 1 + (0.89 * 0.66 / 3.8)).

⁸⁹ Based on Navigant Consulting “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 15

⁹⁰ Ibid.

⁹¹ Consistent with value currently used for EmPOWER Maryland Programs as of October 1, 2017. Derived from C&I common area lighting coincidence.

⁹² Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

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η_{Heat})

Where:

- HF

= Heating Factor or percentage of light savings that must be heated

= 47%⁹³ for interior or unknown location

= 0% for exterior or unheated location
- 0.003412

=Converts kWh to MMBTU
- η_{Heat}

= Efficiency of heating system

=80%⁹⁴
- %FossilHeat

= Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5% ⁹⁵

Annual Water Savings Algorithm

n/a

Incremental Cost

⁹³ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

⁹⁴ U.S. Code of Federal Regulations at 10 CFR 430.32(e).

⁹⁵ Based on KEMA Maryland Energy Baseline Study. Feb 2011.

The lifecycle NPV incremental cost for this retrofit measure is assumed to be \$25 for per control.⁹⁶

Measure Life

The measure life is assumed to be 10 years.⁹⁷

Operation and Maintenance Impacts

n/a

⁹⁶ Costs are from 3/28/18 webscraping of homedepot.com for Landsdowne, MD.

⁹⁷ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

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Connected Lighting

Unique Measure Code(s): RS_LT_RF_CL_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure defines the savings associated with connected lighting that allows for remote user control through a smart device and/or smart hub.

Definition of Baseline Condition

The baseline condition is the efficient, i.e., LED non-connected version of the lamp.

Definition of Efficient Condition

The efficient condition is lighting that is controlled by a smart device and/or home energy hub. The savings for this measure are the estimated incremental control savings compared to a non-connected efficient lamp. Savings come from both reduced hours of operation and from dimming.

Annual Energy Savings Algorithm

$$\Delta kWh = Watts_{EE} * HOURS * SVG_e * ISR * (WHFe_{Heat} + (WHFe_{Cool} - 1)) - Standby_{kWh}$$

Where:

Watts_{EE} = Actual LED wattage.

HOURS = Average hours of use per year:

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Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.86	679 ⁹⁸
Multi Family Common Areas	16.3	5,950 ⁹⁹
Unknown	1.86	679 ¹⁰⁰

SVGe = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.
= 0.49¹⁰¹

ISR = In Service Rate or percentage of units rebated that get installed.

⁹⁸ Based on Navigant Consulting, “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 13. The HOU value is for an efficient lamp.

⁹⁹ Multi family common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. This estimate is consistent with the Common Area “Non-Area Specific” assumption (16.2 hours per day or 5913 annually) from the Cadmus Group Inc., “Massachusetts Multifamily Program Impact Analysis”, July 2012, p 2-4.

¹⁰⁰ “Unknown” assumes a residential interior or in-unit multifamily application.

¹⁰¹ Average of two studies. Navigant Consulting. Department of Energy Solid-State Lighting Program. Energy Savings Estimates of Solid-State Lighting in General Illumination Lighting Applications. September 2016. This study estimates a 71% energy savings from connected lighting in residential applications. (Table F-4). Efficiency Vermont. Smart Lighting & Smart Hub. DIY Install: Does it Yield. August 2016. This study estimates reductions in hours of use of up to 27%. Additionally, the metering study saw significant amounts of dimming of lamps that were on non-dimming circuits, but did not quantify the savings associated with this consumer action.

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$= 0.98^{102}$

$WHFe_{Heat}$ = Waste Heat Factor for Energy to account for electric heating savings from reducing waste heat from efficient lighting (if fossil fuel heating – see calculation of heating penalty in that section).

$= 1 - ((HF / \eta_{Heat}) * \%ElecHeat)$

If unknown assume 0.899^{103}

HF = Heating Factor or percentage of light savings that must be heated

$= 47\%^{104}$ for interior or unknown location
 $= 0\%$ for exterior or unheated location

η_{Heat} = Efficiency in COP of Heating equipment
 = actual. If not available, use¹⁰⁵:

¹⁰² First year ISR of 0.9 (EMPOWER MD Lighting Study, EY5). Assume lifetime ISR of 0.99 (2006-2008 California Residential Lighting Evaluations, and used in the Uniform Methods Project). Assume half of bulbs not installed in year one are installed in year two, and the other half in year three. Using a discount rate of 5%, this gives $0.90 + 0.045 * 0.95 + 0.045 * 0.95^2 = 0.98$

¹⁰³ Calculated using defaults; $1 + ((0.47 / 1.74) * 0.375) = 0.899$

¹⁰⁴ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

¹⁰⁵ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 and again in 2015 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

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System Type	Age of Equipment	HSPF Estimate	η_{Heat} (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.74 ¹⁰⁶

$\% \text{ElecHeat}$ = Percentage of home with electric heat

Heating fuel	$\% \text{ElecHeat}$
Electric	100%
Fossil Fuel	0%
Unknown	37.5% ¹⁰⁷

$\text{WHFe}_{\text{Cool}}$ = Waste Heat Factor for Energy to account for cooling savings from reducing waste heat from efficient lighting.

	$\text{WHFe}_{\text{Cool}}$
Building with cooling	1.087 ¹⁰⁸

¹⁰⁶ Calculation assumes 59% Heat Pump and 41% Resistance which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey. Assume heat pump baseline of 7.7 HSPF.

¹⁰⁷ Based on KEMA Maryland Energy Baseline Study. Feb 2011

¹⁰⁸ The value is estimated at 1.087 (calculated as $1 + (0.33 / 3.8)$). Based on cooling loads decreasing by 33% of the lighting savings (average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC), assuming typical cooling system operating efficiency of 3.8 COP (from the current federal minimum of 13 SEER), converted to COP = SEER/3.412 = 3.8 COP).

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Building without cooling or exterior	1.0
Unknown	1.077 ¹⁰⁹

Standby_{kWh} = Standby power draw of the controlled lamp. Use actual value from manufacturer specification. If not know then assume:
=0.0004¹¹⁰ x 8760 x 75%¹¹¹ = 2.63 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = kWconnected * SVGd * ISR * WHFd * CF

Where:

SVGd = Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.
= 0.49¹¹²

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting

	WHFd
Building with cooling	1.19 ¹¹³

¹⁰⁹ The value is estimated at 1.077 (calculated as 1 + (0.89*(0.33 / 3.8)). Based on assumption that 89% of homes have central cooling (based on KEMA Maryland Energy Baseline Study, Feb 2011.).

¹¹⁰ Lockheed Martin Energy. Home Energy Management System Savings Validation Pilot. Final Report. Prepared for New York State Energy Research and Development Authority. November 2017. P32.

¹¹¹ Lockheed Martin Energy. op. cit. p32.

¹¹² See footnote 4.

¹¹³ The value is estimated at 1.19 (calculated as 1 + (0.66 / 3.8)). See footnote relating to

Building without cooling or exterior	1.0
Unknown	1.17 ¹¹⁴

CF = Summer Peak Coincidence Factor for measure

Installation Location	Type	Coincidence Factor (CF)
Residential interior and in-unit Multi Family	Utility Peak CF	0.059 ¹¹⁵
	PJM CF	0.058 ¹¹⁶
Multi Family Common Areas	PJM CF	0.86 ¹¹⁷
Exterior	PJM CF	0.018 ¹¹⁸
Unknown	Utility Peak CF	0.059
	PJM CF	0.058

Annual Fossil Fuel Savings Algorithm

Heating Penalty if Fossil Fuel heated home (if heating fuel is unknown assume 62.5% of homes heated with fossil fuel):

WHFe for details. Note the 66% factor represents the Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load (i.e. consistent with the PJM coincident definition).

¹¹⁴ The value is estimated at 1.18 (calculated as 1 + (0.89 * 0.66 / 3.8)).

¹¹⁵ Based on Navigant Consulting “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” August 31, 2017, page 15

¹¹⁶ Ibid.

¹¹⁷ Consistent with value currently used for EmPOWER Maryland Programs as of October 1, 2017. Derived from C&I common area lighting coincidence.

¹¹⁸ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

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Δ MMBTUPenalty
ηHeat)

= kWconnected * HOURS * SVGe * ISR * HF * 0.003412) /

Where:

- HF

= Heating Factor or percentage of light savings that must be heated
= 47%¹¹⁹ for interior or unknown location
= 0% for exterior or unheated location
- 0.003412

=Converts kWh to MMBTU
- ηHeat

= Efficiency of heating system
=80%¹²⁰
- %FossilHeat

= Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5% ¹²¹

Annual Water Savings Algorithm

n/a

¹¹⁹ This means that heating loads increase by 47% of the lighting savings. This is based on the average result from REMRate modeling of several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC.

¹²⁰ Minimum federal standard for residential furnaces.

¹²¹ Based on KEMA Maryland Energy Baseline Study. Feb 2011

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure is assumed to be \$11.¹²²

Measure Life

The measure life is assumed to be 15 years.¹²³

Operation and Maintenance Impacts

n/a

¹²² Based on the difference between an LED A-lamp (See LED lamp characterization above) and a connected LED. The latter cost of \$14.99 is from Lockheed Martin Energy. op. cit. p49.

¹²³ ENERGY STAR lifetime minimum requirement for a 15,000-hour A-lamp LED at 679 hrs./yr. ENERGY STAR Program Requirements. Product Specification for Lamps (Light Bulbs). Eligibility Criteria 2.1.

<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf>. While the Maryland HOU estimate yields a 22-year lifetime, this value has been derated to account for obsolescence and removal prior to technical end-of-life.

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Refrigeration End Use

Freezer

Unique Measure Code(s): RS_RF_TOS_RPPFRZ_0616
Effective Date: June 2016
End Date: TBD

Measure Description

This measure relates to the upstream promotion of residential freezers meeting the ENERGY STAR criteria through the Energy Star [Retail Consumer Refrigeration Products Program](#). In the measure, a freezer meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard (NAECA). Energy usage specifications are defined in the table below (note, AV is the freezer Adjusted Volume and is calculated as 1.73*Total Volume):¹²⁴

Product Category	Federal Baseline Maximum Energy Usage in kWh/year ¹²⁵	ENERGY STAR Maximum Energy Usage in kWh/year ¹²⁶
Upright Freezers	8.62*AV+228.3	7.76*AV+205.5
Chest Freezers	7.29*AV+107.8	6.56*AV+97.0

Definition of Baseline Condition

¹²⁴ http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746
¹²⁵ https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
¹²⁶ https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.1%20Consumer%20Refrigeration%20Products%20Final%20Specification_0.pdfhttp://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf

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The baseline equipment is assumed to be a model that meets the federal minimum standard for energy efficiency. The standard varies depending on the type of the freezer (chest or upright freezer) and is defined in the table above.

Definition of Efficient Condition

The efficient equipment is defined as a freezer meeting the efficiency specifications of [current ENERGY STAR requirements](#), as calculated above, or meeting the next tier promoted by RPP, which is 5% more efficient than the EnergyStar minimum.

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{BASE} - kWh_{ESTAR}$

Where:

- kWh_{BASE}
 kWh_{ESTAR}
- = Baseline kWh consumption per year
= As calculated in the table below

= ENERGY STAR kWh consumption per year
=As calculated in the table below

Product Category ¹²⁷	Adj. Volume Use	kWh _{BASE}	kWh _{ESTAR}	kWhEstar + 5%	kWh - Estar	kWh – Estar + 5%	Weighting for unknown configuration
Upright Freezer	24.4	439	395	375	43.78	64	36.74%

¹²⁷ Savings values come from Energy Star Calculations. See ‘RPP Product Analysis 9-23-15.xlsx’

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Chest Freezer	18.0	239	215	204	23.97	35	63.26%
Weighted Average		313	281	267	31.25	46	100%

If product category is unknown assume weighted average values¹²⁸.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh/8760) * TAF * LSAF$$

Where:

TAF = Temperature Adjustment Factor
= 1.23¹²⁹
LSAF = Load Shape Adjustment Factor
= 1.15¹³⁰

¹²⁸ The weighted average unit energy savings is calculated using the market share of upright and chest freezers. The assumed market share, as presented in the table above, comes from 2011 NIA-Frz-2008 Shipments data.

¹²⁹ Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space. Although this evaluation is based upon refrigerators only it is considered a reasonable estimate of the impact of cycling on freezers and gave exactly the same result as an alternative methodology based on Freezer eShape data.

¹³⁰ Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study",

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Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure is \$12.14 for an upright freezer and \$6.62 for a chest freezer¹³¹.

Measure Life

The measure life is assumed to be 11 years¹³².

Operation and Maintenance Impacts

n/a

July 29, 2004 p. 48, (extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 15 through 18, and multiplying by new annual profile).

¹³¹ Based on the Freezer TSD Life-Cycle Cost and Payback Analysis found in Table 8.2.7 Standard-Size Freezers: Average Consumer Cost in 2014, available at:

<http://www.regulations.gov/contentStreamer?documentId=EERE-2008-BT-STD-0012-0128&disposition=attachment&contentType=pdf>

¹³² ENERGY STAR assumes 11 years based on Appliance Magazine U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture for 2005-2012, 2011.

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Refrigerator, Time of Sale

Unique Measure Code(s): RS_RF_TOS_REFRIG_0414
Effective Date: July 2014
End Date: TBD

Measure Description

This measure relates to the purchase and installation of a new refrigerator meeting either ENERGY STAR [Consumer Refrigeration Products V5.1](#)¹³³ or Consortium for Energy Efficiency (CEE) TIER 2 or TIER 3 specifications (defined as requiring >= 10%, >= 15% or >= 20% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The algorithms for calculating Federal Baseline consumption are provided below.¹³⁴ Adjusted Volume is calculated as the fresh volume + (1.63 * Refrigerator Volume). This is a time of sale measure characterization.

Product Category	Federal Baseline Maximum Energy Usage in kWh/year ¹³⁵
1. Refrigerators and Refrigerator-freezers with manual defrost	6.79AV + 193.6
2. Refrigerator-Freezer--partial automatic	7.99AV + 225.0

¹³³ https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.1%20Consumer%20Refrigeration%20Products%20Final%20Specification_0.pdf

¹³⁴ Maximum consumption for ENERGY STAR, CEE Tier 2, and CEE Tier 3 can be calculated by multiplying the federal requirements by 90%, 85%, and 80%, respectively.

¹³⁵ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

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Product Category	Federal Baseline Maximum Energy Usage in kWh/year ¹³⁵
defrost	
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	8.07AV + 233.7
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	8.51AV + 297.8
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	8.85AV + 317.0
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	8.40AV + 385.4
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	8.54AV + 432.8

Definition of Baseline Condition
The baseline condition is a new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency as presented above.

Definition of Efficient Condition
The efficient condition is a new refrigerator meeting either the ENERGY STAR or CEE TIER 2 or TIER 3 efficiency standards as presented above.

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{BASE} * ES$

Where:

kWh_{BASE}

ES

= Annual energy consumption of baseline unit as calculated in algorithm provided in table above.

= Annual energy savings of energy efficient unit. ES is 10% for Energy Star Units, 15% for CEE Tier 2 Units, and 20% for CEE Tier 3 Units.

Illustrative example – do not use as default assumption
A 14 cubic foot Energy Star Refrigerator and 6 cubic foot Freezer, with automatic defrost with side-mounted freezer without through-the-door ice service:

$$\begin{aligned} \Delta kWh &= ((4.91 * (14 + (6 * 1.63))) + 507.5) * (0.10) \\ &= 624.3 * 0.10 \\ &= 62.4 kWh \end{aligned}$$

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8¹³⁶:

Product Category	New Baseline UEC _{BASE}	New Efficient UEC _{EE}	ΔkWh	Product Category

¹³⁶ Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft³ fresh volume and 6.76 ft³ freezer volume.

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		ENERGY STAR	CEE T2	CEE T3	ENERGY STAR	CEE T2	CEE T3	
1. Refrigerators and Refrigerator-freezers with manual defrost	368.8	331.9	313.5	295.0	36.9	55.3	73.8	0.27
2. Refrigerator-Freezer--partial automatic defrost	431.1	388.0	366.5	344.9	43.1	64.7	86.2	0.27
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	441.9	397.7	375.6	353.5	44.2	66.3	88.4	57.24
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	517.4	465.6	439.8	413.9	51.7	77.6	103.5	1.40
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	545.3	490.8	463.5	436.3	54.5	81.8	109.1	16.45
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	602.1	541.9	511.8	481.7	60.2	90.3	120.4	0.27
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	653.1	587.8	555.2	522.5	65.3	98.0	130.6	24.10

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If product category shares are unknown¹³⁷ assume annual energy savings of 51.1 kWh for ENERGY STAR, 76.7 kWh for CEE T2, and 102.2 kWh for CEE Tier 3.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh / 8760) * TAF * LSAF$$

Where:

TAF = Temperature Adjustment Factor
= 1.23¹³⁸
LSAF = Load Shape Adjustment Factor
= 1.15¹³⁹

If volume is unknown, use the following defaults:

¹³⁷ Unknown configuration is based upon a weighted average of the different configurations. Data is taken from the 2011 DOE Technical Support Document (<http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128>http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf). Projected product class market shares from pages 9-12 for year 2014. See 'Refrigerator default calcs.xls' for more details.

¹³⁸ Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space.

¹³⁹ Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 p. 48, (extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 15 through 18, and multiplying by new annual profile).

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Product Category	ΔkW		
	ENERGY STAR	CEE T2	CEE T3
1. Refrigerators and Refrigerator-freezers with manual defrost	0.006	0.009	0.012
2. Refrigerator-Freezer--partial automatic defrost	0.007	0.010	0.014
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	0.007	0.011	0.014
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	0.008	0.013	0.017
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	0.009	0.013	0.018
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	0.010	0.015	0.019
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	0.011	0.016	0.021

If product category is unknown assume 0.008 kW for ENERGY STAR and 0.012 kW for CEE Tier 2, and 0.016 kW for CEE Tier 3.

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is shown below. If configuration is unknown, assume an incremental cost of \$10 for Energy Star, \$33 for CEE Tier 2 and \$44 for CEE Tier 3.¹⁴⁰

Product Category	Energy Star	CEE Tier 2	CEE Tier 3
1. Refrigerators and Refrigerator-freezers with manual defrost	NA	NA	NA
2. Refrigerator-Freezer--partial automatic defrost	NA	NA	NA
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	\$10	\$33	\$44
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	\$13	\$39	\$52
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	\$15	\$41	\$55

¹⁴⁰ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

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6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	\$18	\$45	\$60
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	\$20	\$49	\$66

Measure Life

The measure life is assumed to be 12 Years.¹⁴¹

Operation and Maintenance Impacts

n/a

¹⁴¹ From ENERGY STAR calculator:
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?5035-d681&5035-d681

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Refrigerator, Early Replacement

Unique Measure Code(s): RS_RF_EREP_REFRIG_0414

Effective Date: July 2014

End Date: TBD

Measure Description

This measure relates to the early removal of an existing inefficient Refrigerator unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR [Consumer Refrigeration Products V5.1](#) or CEE Tier 2 or 3 qualifying unit. This measure is suitable for a Low Income or a Home Performance program.

Savings are calculated between the existing unit and the new efficient unit consumption during the assumed remaining life of the existing unit, and between a hypothetical new baseline unit and the efficient unit consumption for the remainder of the measure life.

Definition of Baseline Condition

The baseline condition is the existing inefficient refrigerator unit for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard.

Definition of Efficient Condition

The efficient condition is a new refrigerator meeting either the ENERGY STAR, CEE TIER 2, or CEE Tier 3 efficiency standards (defined as 10%, 15%, or 20% above federal standards respectively).

Annual Energy Savings Algorithm

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Remaining life of existing unit (first 4 years¹⁴²)

$$\Delta \text{kWh} = \text{kWh}_{\text{EXIST}} - \text{kWh}_{\text{EE}}$$

Remaining measure life (next 8 years)

$$\Delta \text{kWh} = \text{kWh}_{\text{BASE}} - \text{kWh}_{\text{EE}}$$

Where:

$\text{kWh}_{\text{EXIST}}$ = Annual energy consumption of existing unit
= 1146¹⁴³

kWh_{BASE} = Annual energy consumption of new baseline unit
= 511.7¹⁴⁴

kWh_{EE} = Annual energy consumption of ENERGY STAR unit
=

¹⁴² Assumed to be 1/3 of the measure life.

¹⁴³ Based on EmPower 2011 Interim Evaluation Report Chapter 5: Lighting and Appliances, Table 15, p33. This suggests an average UEC of 1,146kWh.

¹⁴⁴ kWh assumptions based on using the NAECA algorithms in each product class and calculating a weighted average of the different configurations. Data for weighting is taken from the 2011 DOE Technical Support Document (<http://www.regulations.gov#!documentDetail;D=EERE-2008-BT-STD-0012-0128>http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf). Projected product class market shares from pages 9-12 for year 2014. See 'Refrigerator default calcs.xls' for more details.

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$$= 460.8^{145}$$

Or
$$= \text{Annual energy consumption of CEE Tier 2 unit}$$
$$= 435.2^{146}$$

Or
$$= \text{Annual Energy consumption of CEE Tier 3 unit}$$
$$= 409.4$$

Efficient unit specification	First 4 years ΔkWh	Remaining 8 years ΔkWh	Equivalent Mid Life Savings Adjustment (after 4 years)	Equivalent Weighted Average Annual Savings ¹⁴⁷
ENERGY STAR	685.2	50.9	7.4%	304.7
CEE T2	710.8	76.5	10.8%	330.3
CEE T3	736.6	102.3	13.9%	356.0

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh / 8760) * TAF * LSAF$$

Where:
TAF = Temperature Adjustment Factor

¹⁴⁵ kWh assumptions based on using the ENERGY STAR algorithms in each product class and calculating a weighted average of the different configurations.
¹⁴⁶ kWh assumptions based on 15% less than baseline consumption and calculating a weighted average of the different configurations.
¹⁴⁷ These values are provided in case the utility screening tool does not allow for this mid life baseline adjustment. The values are determined by calculating the Net Present Value of the 12 year annual savings values and finding the equivalent annual savings that produces the same result. The Real Discount Rate of 5.0% is used.

LSAF = 1.23¹⁴⁸
= Load Shape Adjustment Factor
= 1.15¹⁴⁹

Efficient unit specification	First 4 years ΔkW	Remaining 8 years ΔkW	Equivalent Mid Life Savings Adjustment (after 4 years)	Equivalent Weighted Average Annual Savings
ENERGY STAR	0.111	0.008	7.4%	0.049
CEE T2	0.115	0.012	10.8%	0.054
CEE T3	0.119	0.017	13.9%	0.058

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost

¹⁴⁸ Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space.

¹⁴⁹ Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 p. 48, (extrapolated by taking the ratio of existing summer to existing annual profile for hours ending 15 through 18, and multiplying by new annual profile).

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The lifecycle NPV incremental cost for this early replacement measure is shown below. If configuration is unknown, assume an incremental cost of \$341 for Energy Star, \$365 for CEE Tier 2, and \$376 for CEE Tier 3.¹⁵⁰

Product Category	Energy Star	CEE Tier 2	CEE Tier 3
1. Refrigerators and Refrigerator-freezers with manual defrost	NA	NA	NA
2. Refrigerator-Freezer--partial automatic defrost	NA	NA	NA
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	\$341	\$365	\$376
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	\$262	\$287	\$300
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	\$494	\$520	\$534
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	\$542	\$569	\$584

¹⁵⁰ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Product Category	Energy Star	CEE Tier 2	CEE Tier 3
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	\$466	\$495	\$511

Measure Life

The measure life is assumed to be 12 Years.¹⁵¹

Operation and Maintenance Impacts

n/a

¹⁵¹ From ENERGY STAR calculator:
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?5035-d681&5035-d681

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Refrigerator and Freezer, Early Retirement

Unique Measure Code(s): RS_RF_ERE~~T~~_REFRIG_0414, RS_RF_ERE~~T~~_FREEZE_0414

Effective Date: June 2014

End Date: TBD

Measure Description

This measure involves the removal of an existing inefficient refrigerator¹⁵² from service, prior to its natural end of life (early retirement). The program should target refrigerators with an age greater than 10 years, though it is expected that the average age will be greater than 20 years based on other similar program performance. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit¹⁵³.

Definition of Baseline Condition

The existing refrigerator baseline efficiency is based upon evaluation of a number of existing programs and evaluations.

Definition of Efficient Condition

The existing inefficient refrigerator is removed from service and not replaced.

Annual Energy Savings Algorithm

¹⁵² This measure assumes a mix of primary and secondary refrigerators will be replaced. By definition, the refrigerator in a household's kitchen that satisfies the majority of the household's demand for refrigeration is the primary refrigerator. One or more additional refrigerators in the household that satisfy supplemental needs for refrigeration are referred to as secondary refrigerators.

¹⁵³ Note that the hypothetical nature of this measure implies a significant amount of risk and uncertainty in developing the energy and demand impact estimates.

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Refrigerators:

Energy savings for retired refrigerators are based upon a linear regression model using the following coefficients¹⁵⁴:

Independent Variable Description	Estimate Coefficient
Intercept	0.80460
Age (years)	0.02107
Pre-1990 (=1 if manufactured pre-1990)	1.03605
Size (cubic feet)	0.05930
Dummy: Single Door (=1 if single door)	-1.75138
Dummy: Side-by-Side (= 1 if side-by-side)	1.11963
Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit)	0.55990
Interaction: Located in Unconditioned Space x HDD/365.25	-0.04013
Interaction: Located in Unconditioned Space x CDD/365.25	0.02622

$$\Delta \text{kWh} = [0.80460 + (\text{Age} * 0.02107) + (\text{Pre-1990} * 1.03605) + (\text{Size} * 0.05930) + (\text{Single-Door} * -1.75138) + (\text{Side-by-side} * 1.11963) + (\text{Primary} * 0.55990) +$$

¹⁵⁴ Memo from Navigant Consulting to EmPOWER Maryland utilities, Appliance Recycling Program, Regression Modeling Analysis, Evaluation Year 6, July 12, 2016.

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$$(\text{HDD}/365.25 * \text{Unconditioned} * -0.04013) + (\text{CDD}/365.25 * \text{Unconditioned} * 0.02622)] * 365.25 * \text{Part Use}$$

Where:

HDD = Heating Degree Days
= dependent on location. Use actual for location or defaults below¹⁵⁵

Location	Heating Degree Days (65°F set point)	HDD / 365.25
Wilmington, DE	4,298	11.8
Baltimore, MD	4,529	12.4
Washington, DC	3,947	10.8

CDD = Cooling Degree Days
= dependent on location. Use actual for location or defaults below¹⁵⁶

Location	Cooling Degree Days (65°F set point)	CDD / 365.25
Wilmington, DE	1,162	3.2
Baltimore, MD	1,266	3.5
Washington, DC	1,431	3.9

¹⁵⁵ The 10-year average annual heating degree day value is calculated for each location, using a balance point of 65 degrees as used in the EmPower Appliance Recycling Evaluation.
¹⁵⁶ Ibid.

Part Use Factor = To account for those units that are not running throughout the entire year as reported by the customer. Default of 0.95 for refrigerators and 0.86 for freezers.¹⁵⁷

Illustrative example – can be used as default assumption only if required data tracking is not available.

Using participant population mean values from BGE EY4 and default part use factor:

$$\begin{aligned} \Delta \text{kWh} &= [0.80460 + (18.61 * 0.02107) + (0.20 * 1.03605) + (19.43 * 0.05930) + (0.02 * -1.75138) + (0.34 * 1.11963) + (0.64 * 0.55990) + (2.91 * -0.04013) + (0.77 * 0.02622)] * 365.25 * 0.95 \\ &= 1,098 \text{ kWh} \end{aligned}$$

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients¹⁵⁸:

Independent Variable Description	Estimate Coefficient
Intercept	-0.95470
Age (years)	0.0453

¹⁵⁷ Based on EmPower DRAFT EY6 Participant Survey Results: Appliance Recycling Program Report
¹⁵⁸ Memo from Navigant Consulting to EmPOWER Maryland utilities, Appliance Recycling Program, Regression Modeling Analysis, Evaluation Year 6, July 12, 2016..

Pre-1990 (=1 if manufactured pre-1990)	0.54341
Size (cubic feet)	0.12023
Chest Freezer Configuration (=1 if chest freezer)	0.29816
Interaction: Located in Unconditioned Space x HDD/365.25	-0.03148
Interaction: Located in Unconditioned Space x CDD/365.25	0.08217

$$\Delta \text{kWh} = [-0.95470 + (\text{Age} * 0.04536) + (\text{Pre-1990} * 0.54341) + (\text{Size} * 0.12023) + (\text{Chest Freezer} * 0.29816) + (\text{HDDs}/365.25 * \text{Unconditioned} * -0.03148) + (\text{CDDs}/365.25 * \text{Unconditioned} * 0.08217)] * 365.25 * \text{Part Use Factor}$$

Illustrative example – can be used as default assumption only if required data tracking is not available.

Using participant population mean values from BGE EY4 and default part use factor:

$$\begin{aligned} \Delta \text{kWh} &= [-0.95470 + (23.79 * 0.04536) + (0.46 * 0.54341) + (15.86 * 0.12023) + (0.21 * 0.29816) + (6.83 * -0.03148) + (1.80 * 0.08217)] * 365.25 * 0.86 \\ &= 715 \text{ kWh} \end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = (\Delta \text{kWh}/8760) * \text{TAF} * \text{LSAF}$$

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Where:

TAF = Temperature Adjustment Factor
= 1.23¹⁵⁹
LSAF = Load Shape Adjustment Factor
= 1.066¹⁶⁰

Illustrative example – can be used as default assumption only if required data tracking is not available.

Using participant population mean values from BGE EY4 and default part use factor:

Refrigerator:

$$\Delta kW = 1098/8760 * 1.23 * 1.066$$
$$= 0.164 \text{ kW}$$

Freezer:

$$\Delta kW = 715/8760 * 1.23 * 1.066$$

¹⁵⁹ Temperature adjustment factor based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47) and assuming 78% of refrigerators are in cooled space (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates) and 22% in un-cooled space.

¹⁶⁰ Daily load shape adjustment factor also based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 p. 48, using the average Existing Units Summer Profile for hours ending 15 through 18.

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= 0.107 kW

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this measure is the actual cost associated with the removal and recycling of the secondary refrigerator.

Measure Life
The measure life is assumed to be 8 Years.¹⁶¹

Operation and Maintenance Impacts
n/a

¹⁶¹ KEMA “Residential refrigerator recycling ninth year retention study”, 2004.

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Heating Ventilation and Air Conditioning (HVAC) End Use

Central Furnace Efficient Fan Motor

Unique Measure Code(s): RS_HV_RF_FANMTR_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure involves the installation of a high efficiency brushless permanent magnet fan motor (BPM or ECM), hereafter referred to as “efficient fan motor”. This measure applies only when retrofitting an existing furnace or central air conditioning unit with a new fan motor.

For homes that install an efficient furnace fan and have central A/C, both the cooling and heating savings values should be included.

Circulation mode savings should also be attributed to this measure to capture operational savings that occur outside of heating and cooling modes. Note that circulation mode savings is calculated separately from heating and cooling savings.

Definition of Baseline Condition

A standard low-efficiency permanent split capacitor (PSC) fan motor.

Definition of Efficient Condition

A high efficiency brushless permanent magnet fan motor (BPM or ECM).

Annual Energy Savings Algorithm Annual kWh savings = Heating Season kWh Savings + Cooling Season kWh Savings + Circulation mode kWh Savings
Heating Season kWh Savings from efficient fan motor = 168.9¹⁶²

¹⁶² Final_EmPOWER_EY5 HVAC ECM Memo_09-10-15.docx

Cooling Season kWh Savings from efficient fan motor is calculated using the following algorithm:

$$\text{cooling kWh savings} = \Delta kW \times EFLH_{\text{cool}}$$

Where:

ΔkW = .182¹⁶³

EFLH_{cool} = technology and location specific value from tables below

Central AC EFLH_{cool}

Location	EFLH _{cool}
Wilmington, DE	524 ¹⁶⁴
Baltimore, MD	542 ¹⁶⁵
Washington, DC	681

Air Source Heat Pump EFLH_{cool}

Location	EFLH _{cool}

¹⁶³ Connected load reduction based on Cadmus report “Brushless Fan Motors Impact Evaluation” for MA http://ma-eeac.org/wordpress/wp-content/uploads/Brushless-Fan-Motors-Impact-Evaluation_Part-of-the-Massachusetts-Residential-Retrofit-Low-Income-Program-Area-Evaluation.pdf

¹⁶⁴ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

¹⁶⁵ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

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Wilmington, DE	719 ¹⁶⁶
Baltimore, MD	744 ¹⁶⁷
Washington, DC	935

Circulation mode is when the HVAC fan is operational for ventilation only. Savings is calculated by multiplying the circulation mode run time in hours by the ΔkW between the baseline and efficient motors. Heating Season fuel energy penalty:

$$\text{Additional heating fuel (MMBTU)} = \frac{\Delta kWh_{ECM \text{ Heating}}}{AFUE \times 293.1}$$

Where:

$\Delta kWh_{ECM \text{ Heating}}$ = 168.9kWh of electrical savings during heating mode
 AFUE = Installed Furnace AFUE
 293.1 = Constant for conversion from kWh to MMBTU

Example of heating fuel penalty when ECM motor is retrofitted into an 85% AFUE furnace:

¹⁶⁶ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (744 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

¹⁶⁷ Based on average of 5 utilities in Maryland from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31 2013) Residential HVAC Program." April 4, 2014, Table 30, page 48.

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additional annual MMBTU = $168.9 / (.85 \times 293.1) = .68$ MMBTU

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0$ ¹⁶⁸

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental costs for this measure are provided below.¹⁶⁹

¹⁶⁸ See write up in Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, page 38-39.

¹⁶⁹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Incremental Costs Central Furnace Efficient Fan Motor
Retrofit
\$287

Measure Life
The measure life is assumed to be 18 years.

Operation and Maintenance Impacts
n/a

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Room Air Conditioner, Time of Sale

Unique Measure Code(s): RS_HV_TOS_RA/CES_0414, RS_HV_TOS_RA/CT2_0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a room air conditioning unit that meets the ENERGY STAR minimum qualifying efficiency specifications presented below. Note that if the AC unit is connected to a network in a way to enable it to respond to energy related commands, it gets a 5% extra CEER allowance. In these instances, the efficient CEER would be 0.95 multiplied by the appropriate CEER from the table below.

Commented [A1]: Note - the federal minimums for this measure increase starting 1/1/2024 and will need to be updated

Product Type and Class (BTU/hour)		Federal Standard with louvered sides (CEER)	Federal Standard without louvered sides (CEER)	ENERGY STAR with louvered sides (CEER)	ENERGY STAR without louvered sides (CEER)
Without Reverse Cycle	< 8,000	11.0	10.0	12.1	11.0
	8,000 to 10,999	10.9	9.6	12.0	10.6
	11,000 to 13,999	10.9	9.5	12.0	10.5
	14,000 to 19,999	10.7	9.3	11.8	10.2
	20,000 to 24,999	9.4	9.4	10.3	10.3
	25,000 to 27,999	9.0	9.4	10.3	10.3
	>=28,000	9.0	9.4	9.9	10.3
	<14,000	NA	9.3	NA	10.2

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With Reverse Cycle	$\geq 14,000$	NA	8.7	NA	9.6
	$< 20,000$	9.8	NA	10.8	NA
	$\geq 20,000$	9.3	NA	10.2	NA
Casement only		9.5		10.5	
Casement-Slider		10.4		11.4	

Definition of Baseline Condition

The baseline condition is a window AC unit that meets the minimum federal efficiency standards presented above.

Definition of Efficient Condition

The efficient condition is a window AC unit that meets the ENERGY STAR v4.0¹⁷⁹.

Annual Energy Savings Algorithm

$$\Delta kWh = (Hours * BTU/hour * (1/CEER_{base} - 1/CEER_{ee}))/1000$$

Where:

Hours — Run hours of Window AC unit

¹⁷⁹

https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.2%20Room%20Air%20Conditioners%20Specification_0.pdf

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$$\Delta kWh = (325 * 8500 * (1/10.9 - 1/12)) / 1000 = 23.2 kWh$$

~~474 Minimum qualifying for ENERGY STAR most common Room AC type - 8000-14,999 capacity range with louvered sides.~~

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \text{BTU/hour} * (1/\text{CEER}_{\text{base}} - 1/\text{CEER}_{\text{ee}}) / 1000 * CF$$

Where:

- CF = Summer Peak Coincidence Factor for measure
- CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.31¹⁷⁵
- CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.3¹⁷⁶

Using deemed values above:

$$\begin{aligned} \Delta kW_{\text{SSP}} &= (8500 * (1/10.9 - 1/12)) / 1000 * 0.31 \\ &= 0.022 \text{ kW} \end{aligned}$$

$$\Delta kW_{\text{PJM}}$$

¹⁷⁵ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

¹⁷⁶ Consistent with coincidence factors found in:

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).

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$$\begin{aligned} &= (8500 * (1/10.9 - 1/12)) / 1000 * 0.30 \\ &= 0.021 \text{ kW} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

_____ n/a

Annual Water Savings Algorithm

_____ n/a

Incremental Cost¹⁷⁷

_____ The lifecycle NPV incremental cost for this time of sale measure is \$20.

Measure Life

_____ The measure life is assumed to be 12 years.¹⁷⁸

Operation and Maintenance Impacts

_____ n/a

¹⁷⁷ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update, 2017*. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010–2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

¹⁷⁸ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. <http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.pdf>

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Room Air Conditioner, Early Retirement / Recycling

Unique Measure Code: RS_HV_ERET_RA/C_0414
Effective Date: January 2023
End Date: TBD

Measure Description

This measure describes the savings resulting from implementing a drop-off service taking existing working inefficient Room Air Conditioner units from service, prior to their natural end of life. Like the Refrigerator Early Retirement / Recycling measure, this measure quantifies savings associated with the removal of room air conditioner units from service (rather than transferred to another location in the home or another household) and thus does not decrement savings due to retired units that are replaced in participants' homes.

Definition of Baseline Condition

The baseline condition is the existing room air conditioning unit.

Definition of Efficient Condition

The existing room air conditioning unit is removed from service and dismantled/recycled.

Annual Energy Savings Algorithm

$$\Delta kWh = ((Hours * BTUH * (1/EER_{exist}))/1,000) * Part Use Factor$$

Where:

$$Hours = \text{Run hours of Window AC unit} \\ = 325^{179}$$

¹⁷⁹ VEIC calculated the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling (provided by AHRJ: https://www.energystar.gov/sites/default/uploads/buildings/old/files/CentralAC_Calculator.xls) at 31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

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$BTU/hour$ — = Capacity of replaced unit
 = Actual or 8,500 if unknown¹⁸⁰
 EER_{exist} — = Efficiency of existing unit in BTUs per Watt-hour
 = Actual or 9.8 if unknown¹⁸¹
 Part Use Factor — = To account for those units that are not in daily use throughout the entire cooling season as reported by the participant
 = Actual or 0.34¹⁸² if unknown

Illustrative example — **do not use as default assumption**

The turn in of an 8,500 BTU/h, 9.8 EER unit:

$$\Delta kWh = ((325 * 8,500 * (1/9.8))/1,000) * 0.34$$

$$= 96 kWh$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (BTUH * (1/EER_{exist})/1,000) * \text{Part Use Factor} * CF$$

Where:

CF_{SSP} — = Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)
 = 0.31¹⁸³

CF_{PJM} — = PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather

¹⁸⁰ Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008. The New York Times reports a similar size (8,000 BTU/hour) as the most popular size for residential room air conditioners (<https://www.nytimes.com/wirecutter/reviews/best-air-conditioner/>).

¹⁸¹ Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER was introduced later.

¹⁸² Source: Cadmus analysis, EmPOWER 2018 P1 & P2 ARP participant survey

¹⁸³ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

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$$= 0.3^{184}$$

Illustrative example (using Summer System Peak Coincidence Factor)—do not use as default assumption

The turn-in of an 8500 BTUh, 9.8 EER unit:

$$\Delta kW_{SSP} = ((8,500 * (1/9.8))/1,000) * 0.34 * 0.31$$

$$= 0.09 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Measure Life
The measure life is assumed to be 3 years.¹⁸⁵

¹⁸⁴ Consistent with coincidence factors found in:
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).

¹⁸⁵ 3 years of remaining useful life based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

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Dehumidifier, Early Retirement / Recycling

Unique Measure Code(s): RS-AP-ERET-DEHUMID-0420

Effective Date: January 2023

End Date: TBD

Measure Description

This measure describes the savings resulting from removing an existing, operating dehumidifier from service prior to its natural end of life. The program should target, but not be limited to, dehumidifiers put into service prior to June 2019. Like the Refrigerator Early Retirement / Recycling measure, this measure quantifies savings associated with the removal of inefficient dehumidifiers from service (rather than transferred to another household) and thus does not decrement savings due to retired units that are replaced in participants' homes.

Definition of Baseline Condition

The baseline condition is the existing dehumidifier.

Definition of Efficient Condition

The existing dehumidifier is removed from service and dismantled/recycled.

Energy Savings Algorithm

Remaining life kWh savings =

$$\text{Capacity} \times \frac{0.473}{24} \times \text{Full Load hours} \times \frac{1}{L \text{ per kWh}} \times \text{Part Use Factor}$$

Where:

- Capacity = Capacity of the unit (pints/day)
- 0.473 = Constant to convert Pints to Liters
- 24 = Constant to convert Liters/day to Liters/hour
- Full Load Hours = Run hours per year

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_____ = Actual or 1632 ⁴⁸⁶

$L_{per kWh}$ _____ = Liters of water per kWh consumed, as provided in table below.
Values reflect a manufacture date range that coincides with
timing of federal efficiency standards.

Part Use Factor = To account for those units that are not in daily use throughout
the entire cooling season as reported by the participant.

_____ = Actual or 0.71 ⁴⁸⁷ if unknown

Annual kWh savings results for each capacity class (after adjusting for a part use factor of 0.71)
are presented in the table below reflecting two recent federal standards as baseline. If the
capacity of installed units is collected, the savings should be calculated using the algorithm. If
the capacity is unknown, a default average value is provided. If the age of recycled units is
collected, the savings should use the applicable Federal Standard L/kWh value (manufacture
date before October 2012, or after.) If the age is unknown, apply the 2012 Federal Standard. If
the unit being removed is ENERGY STAR labeled, a custom calculation will be required.

				Annual kWh Savings	
Capacity (pints/day) <u>Range</u>	Capacity of existing unit (pints/day)	2007 Federal Standard <u>(≥ L/kWh) ⁴⁸⁶</u>	2012 Federal Standard <u>(≥ L/kWh) ⁴⁸⁶</u>	Mfr date before Oct 2012	Mfr date between Nov 2012 and June 2019

⁴⁸⁶ Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator
https://www.sfwmd.gov/sites/default/files/documents/calculator_energy_star_res_appliance_savings.xlsx
The ENERGY STAR Dehumidifier Calculator cites:
Electricity Consumption by Small End Uses in Residential Buildings, Report to Office of Building
Equipment, U.S. Department of Energy, 1998

⁴⁸⁷ Source: Cadmus analysis, EmPOWER 2018 P1 & P2 ARP participant survey

≤25	20	1	1.35	457	339
>25 to ≤35	30	1.2	1.35	571	508
>35 to ≤45	40	1.3	1.5	703	609
>45 to ≤54	50	1.3	1.6	878	714
>54 to ≤75	65	1.5	1.7	990	873
>75 to ≤185	130	2.25	2.5	1319	1188
Average	56	1.43	1.67	895	765

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kWh / 4,392 \text{ Hours}$$

Where:kWh = annual kWh savingsHours = Total hours in summer dehumidification season
= 4,392 hours¹⁹⁰

Capacity (min./day) Range	ΔkW before 2013	ΔkW 2013- 2019
≤25	0.104	0.077
>25 to ≤35	0.130	0.116
>35 to ≤45	0.160	0.139
>45 to ≤54	0.200	0.163

¹⁹⁰ Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%. The assumption of evenly distributed dehumidifier loads across hours of the day is supported by the Massachusetts Baseline Load Shape Study (RES-1), which shows nearly flat summer peak day load shape (see Figure 47, Available online at <https://ma-eeac.org/wp-content/uploads/RES-1-FINAL-Comprehensive-Report-2018-07-27.pdf>.)

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<u>>54 to ≤ 75</u>	<u>0.225</u>	<u>0.199</u>
<u>>75 to ≤ 185</u>	<u>0.300</u>	<u>0.270</u>
<u>Average</u>	<u>0.204</u>	<u>0.174</u>

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Measure Life

The measure life is assumed to be 3 years¹⁹¹.

¹⁹¹ 3 years of remaining useful life based on Room AC early retirement/recycling values from Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year. Without primary research, it is assumed that Room ACs and dehumidifiers have similar measure life at retirement; the measure life for both time of sale measures is 12 years.

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ENERGY STAR Central A/C

Unique Measure Code(s): RS_HV_TOS_CENA/C_0518, RS_HV_EREP_CENA/C_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the installation of a new Central Air Conditioning ducted split system meeting ENERGY STAR V6.0¹⁹² efficiency standards presented below. [This measure is not intended to serve heat pumps.](#)

~~*Note*—Federal minimum efficiencies for units manufactured prior to 1/1/2023 and installed after that date, utilizing the SEER testing rating instead of the SEER2 testing specifications, will need to meet the minimum efficiencies stated below.~~

Manufactured Prior to 1/1/2023		
Efficiency Level	SEER Rating	EER Rating
Federal Standard	14.154	11.8 ¹⁹³
ENERGY STAR	15	12.5

~~Federal Efficiency Minimum Updates after 1/1/2023¹⁹⁴~~

¹⁹² [https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.0%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20and%20Partner%20Co](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.0%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20and%20Partner%20Commitments_0.pdf)
[mmittments_0.pdf](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.0%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20and%20Partner%20Commitments_0.pdf)

¹⁹³ The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.

¹⁹⁴ <https://www.seer2.com/region-southeast.html>

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Effective January 1, 2023, cooling products will be subject to regional minimum efficiencies. These efficiencies will depend on the region in which the product is installed. These units will need to adhere to the new testing measures and meet SEER2 rating requirements.

Note - Federal minimum efficiencies for units manufactured or installed prior to 1/1/2023 and installed after that date, utilizing the SEER testing rating instead of the SEER2 testing specifications, will need to meet the minimum efficiencies stated below.

Manufactured or Installed After 1/1/2023Manufactured After 1/1/2023					
Efficiency Level	Unit Size (BTUh)	SEER2 Rating	Equivalent SEER Rating	EER2 Rating	Equivalent EER Rating
Federal Standard, Southeast Region	< 45,000 BTUh	14.3	15.0	11.92-11.8 ¹⁹⁵	15.012.3
	>= 45,000 BTUh	13.8	14.5	11.62-0	14.512.0
ENERGY STAR	All Sizes	15.2	16	12.05	12.56

This measure could relate to:

- a) Time of Sale – the installation of a new Central AC system meeting ENERGY STAR specifications replacing an existing unit at the end of its useful life or the installation of a new system in a new home. Most units bought at a store receiving prescriptive incentives are considered time of sale.

¹⁹⁵ The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.

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- b) Early Replacement – the early removal of an existing, functioning unit prior to its natural end of life and replacement with an ENERGY STAR unit. Savings are calculated between existing unit and efficient unit consumption during the assumed remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Comprehensive building efficiency improvements will reduce load, and may lead to downsizing of space conditioning equipment. To properly account for these interactive effects, energy modeling should be performed and those results should be used for savings attribution in place of savings algorithms shown here. Effects of HVAC downsizing can be attributed to either weatherization or HVAC, but not both.

Definition of Baseline Condition

The baseline condition for the Time of Sale is a central air conditioning ducted split system that meets the minimum Federal standards as presented above.

The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the new, efficient equipment measure life. If the existing equipment efficiency is unknown, use the prevailing federal efficiency standard based on age per table below for split systems.

Note that to be characterized as early replacement, the age of the unit must not exceed the measure life of 18 years.

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Split System Air Conditioner Federal Baselines for Southeast ¹⁹⁶	
Manufacture Date	SEER
January 1993 through January 2006	10.0
February 2006 through December 2014	13.0
After January 1 2015	14.0
After January 1, 2023	15

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Definition of Efficient Condition

The efficient condition is a central air conditioning ducted split system that meets the ENERGY STAR standards presented above.

Annual Energy Savings Algorithm

SEER, EER, and HSPF should be replaced with SEER2, EER2, and HSPF2 ratings in the below equations where appropriate.

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Time of Sale:

$$\Delta kWh = Hours \times \frac{(BTU_{Hexist} / SEER_{base}) - (BTU_{Hee} / SEER_{ee})}{1000}$$

¹⁹⁶ <https://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>

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Early replacement¹⁹⁷:

ΔkWH for remaining life of existing unit:

$$\Delta\text{kWH} = \text{Hours} \times \frac{(\text{BTUHexist} / \text{SEERexist}) - (\text{BTUHee} / \text{SEERee})}{1000}$$

ΔkWH for balance of measure life:

$$\Delta\text{kWH} = \text{Hours} \times \frac{(\text{BTUHexist} / \text{SEERbase}) - (\text{BTUHee} / \text{SEERee})}{1000}$$

Where:

Hours = Full load cooling hours
Dependent on location as below:

Location	Run Hours

¹⁹⁷ The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

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Wilmington, DE	524 ¹⁹⁸
Baltimore, MD	542 ¹⁹⁹
Washington, DC	681

BTUHexist = Size of existing equipment in BTU/hour (tons x 12,000BTU/hr)
= Actual installed

BTUHee = Size of new efficient equipment in BTU/hour (tons x 12,000BTU/hr)

SEERbase = Seasonal Energy Efficiency Ratio Efficiency of baseline unit
= 15.4²⁰⁰

SEERexist = Seasonal Energy Efficiency Ratio of existing unit (kBTU/kWh)

¹⁹⁸ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

¹⁹⁹ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

²⁰⁰ Minimum Federal Standard.

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= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11.²⁰¹

SEER_{ee} = Seasonal Energy Efficiency Ratio Efficiency of ENERGY STAR unit
= Actual installed

SEER_{2ee} = Seasonal Energy Efficiency Ratio Efficiency 2 of ENERGY STAR unit
SEER 2 rating stands for Season Energy Efficiency Ratio 2. This is the new main energy efficiency ratio developed in 2016 and introduced by the US Department Of Energy in 2023 and onward. In its essence, SEER2 is the same (equation, calculation) as SEER, but under different test conditions.
= Actual installed after 1/1/2023

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Illustrative example – do not use as default assumption

²⁰¹ Based on Itron and Cadmus unpublished analysis of standard efficiency units by age of unit from Energy Information Administration, Residential Energy Consumption Survey, 2015, AHRI historical shipments data (<http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx>), and Energy Star historical shipments data (https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?52f9-67a), and mortality curve assumptions drawn from Cory Welch, Estimating the Useful Life of Residential Appliances, ACEEE Summer Study 2010 paper (<http://aceee.org/files/proceedings/2010/data/papers/1977.pdf>).

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Time of Sale example: a 3-ton, 15.4 SEER unit upgraded from lower efficiency to higher, with an equivalent sized unit with SEER rating of 16.5 in Baltimore:

$$\Delta \text{kWh} = 542 \times ((36000/15.4) - (36000/16.5)) / 1000$$

$$= 81.393 \text{ kWh}$$

Early Replacement example where there is a “right-sizing” adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): a 3-ton, 11 SEER unit replaced with a 2-ton with SEER rating of 15 in Baltimore:

$$\begin{aligned} \Delta \text{kWh (f remaining life)} &= 542 \times ((36000/11) - (24000/15)) / 1000 \\ &= 907 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh (through end of life)} &= 542 \times ((36000/14) - (24000/15)) / 1000 \\ &= 526 \text{ kWh} \end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

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$$\Delta kW = \frac{(BTU_{Hexist} \times 1 / EER_{base}) - (BTU_{Hee} \times 1 / EER_{ee})}{1000 \times CF}$$

Early replacement:

ΔkW for remaining life of existing unit (remaining life):

$$\Delta kW = \frac{(BTU_{Hexist} \times 1 / EER_{exist}) - (BTU_{Hee} \times 1 / EER_{ee})}{1000 \times CF}$$

ΔkW for remaining measure life (through end of life):

$$\Delta kW = \frac{(BTU_{Hexist} \times 1 / EER_{base}) - (BTU_{Hee} \times 1 / EER_{ee})}{1000 \times CF}$$

Where:

- EERbase* = Energy Efficiency Ratio Efficiency of baseline unit
= ~~12.318~~
- EERexist* = EER Efficiency of existing unit
= Actual EER of unit should be used, if EER is unknown, use 9.9²⁰²
- EERee* = Energy Efficiency Ratio Efficiency of ENERGY STAR unit
= Actual installed
- CF_{SSP}* = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)

²⁰² Based on SEER of 11, using a formula to give 9.9 EER. The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 \times SEER^2) + (1.12 \times SEER)$. See Wassmer, M. (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations," Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

$$\begin{aligned} CF_{PJM} &= 0.69^{203} \\ &= \text{PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather} \\ &= 0.66^{204} \end{aligned}$$

Illustrative example – do not use as default assumption.

Time of Sale example: a 3-ton unit with efficient EER rating of 12.5 upgraded from lower efficiency to higher, with same size unit:

$$\Delta kW_{SSP} = ((36000 \times 1/11.8) - (36000 \times 1/12.5)) / 1000 \times 0.69$$

$$= 0.12 \text{ kW}$$

$$\Delta kW_{PJM} = ((36000 \times 1/11.8) - (36000 \times 1/12.5)) / 1000 \times 0.66$$

$$= 0.11 \text{ kW}$$

Early Replacement example where there is a “right-sizing” adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): an existing 3-ton unit with EER 9.9 is replaced by a 2-ton unit with EER rating of 12.5 in Baltimore:

²⁰³ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

²⁰⁴ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

ΔkW for remaining life of existing unit:

$$\begin{aligned}\Delta kW_{SSP} &= ((36000 \times 1/9.9) - (24000 \times 1/12.5)) / 1000 \times 0.69 \\ &= 1.18 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= ((36000 \times 1/9.9) - (24000 \times 1/12.5)) / 1000 \times 0.66 \\ &= 0.1.13 \text{ kW}\end{aligned}$$

ΔkW for remaining measure life:

$$\begin{aligned}\Delta kW_{SSP} &= ((36000 \times 1/11.8) - (24000 \times 1/12.5)) / 1000 \times 0.69 \\ &= 0.78 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= ((36000 \times 1/11.8) - (24000 \times 1/12.5)) / 1000 \times 0.66 \\ &= 0.75 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

An ECM fan motor is required for a CAC to achieve 16 SEER or higher. If the air handler for the CAC unit is attached to an existing furnace (common), the existing forced

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air system can be retrofitted either with an ECM motor or by replacing the existing furnace with a new 80 AFUE gas furnace that includes an ECM motor.²⁰⁵

The lifecycle NPV incremental costs per ton for this measure are provided below:²⁰⁶

SEER	Time of Sale			Early Replacement		
	CAC Alone	CAC w/ECM	CAC w/Furnace & ECM	CAC Alone	CAC w/ECM	CAC w/Furnace & ECM
16	\$199	\$376	\$816	\$507	\$1,040	\$2,359
17	\$298	\$476	\$915	\$606	\$1,140	\$2,458
18	\$397	\$575	\$1,015	\$706	\$1,239	\$2,558
19	\$497	\$674	\$1,114	\$805	\$1,338	\$2,657
20	\$596	\$774	\$1,213	\$904	\$1,438	\$2,756
21	\$695	\$873	\$1,313	\$1,004	\$1,537	\$2,856

Measure Life

²⁰⁵ Contractors may be reluctant to retrofit ECM fans due to concerns about compatibility and voiding manufacturer warranties.

²⁰⁶ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017.

Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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The measure life is assumed to be 18 years.²⁰⁷

Remaining life of existing equipment is assumed to be 6 years²⁰⁸ unless otherwise known.

Operation and Maintenance Impacts

n/a

²⁰⁷ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

²⁰⁸ Assumed to be one third of the effective useful life.

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Air Source Heat Pump

Unique Measure Code: RS_HV_TOS_ASHP_0518, RS_HV_EREP_ASHP_0518,
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the installation of a new Air Source Heat Pump split system meeting ENERGY STAR V6.0²⁰⁹ efficiency standards presented below:

Manufactured and Installed Prior to 1/1/2023			
Efficiency Level	HSPF	SEER Rating	EER Rating ²¹⁰
Federal Standard as of 1/1/2015 ²¹¹	8.2	14	11.8 ²¹²
ENERGY STAR	8.5	15	12.5

Federal Efficiency Minimum Updates after 1/1/2023

²⁰⁹ https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.0%20Central%20Air%20Conditioner%20and%20Heat%20Pump%20Final%20Specification%20and%20Partner%20Commitments_0.pdf

²¹⁰ HSPF, SEER and EER refer to Heating Seasonal Performance Factor, Seasonal Energy Efficiency Ratio, and Energy Efficiency Ratio, respectively

²¹¹ Existing SEER14 heat pump units manufactured prior to 1/1/2023 may still be installed after that date.

²¹² The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER²) + (1.12 * SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

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Effective January 1, 2023, cooling heat pump products will be subject to regional minimum efficiencies. These efficiencies will depend on the region in which the product is installed. These units will need to adhere to the new testing measures and meet SEER2 and HSPF2 rating requirements.

Note - Federal minimum efficiencies for units manufactured or installed prior to 1/1/2023 and installed after that date, utilizing the SEER testing rating instead of the SEER2 testing specifications, will need to meet the minimum efficiencies stated below. All units manufactured after 1/1/2023 must meet the SEER2 and HSPF2 ratings in the table below.

Manufactured or Installed After 1/1/2023Manufactured or Installed After 1/1/2023						
Efficiency Level	SEER2 Rating	Equivalent SEER Rating	HSPF2 Rating	Equivalent HSPF Rating	EER2 Rating	Equivalent EER Rating
Federal Standard, Southeast Region	14.3	15.0	15.50	8.8		12.3
	13.8	14.5				12.0

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					<u>11.9</u> ²¹³		Formatted: Font: Bold
					<u>11.6</u>		
<u>ENERGY STAR</u>	<u>15.2</u>	<u>16</u>	<u>7.8</u>	<u>9.2</u>	<u>12.0</u>	<u>12.5</u>	Formatted: Font: Bold
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This measure could relate to:

- a) Time of Sale – the installation of a new Air Source Heat Pump system meeting ENERGY STAR specifications replacing an existing unit at the end of its useful life or the installation of a new system in a new home. Most units bought at a store receiving prescriptive incentives are considered time of sale.
- b) Early Replacement – the early removal of existing functioning electric heating and cooling heat pump system prior to its natural end of life and replacement with an ENERGY STAR unit. Dual baseline savings are calculated between existing unit and efficient unit consumption during the assumed remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures.

²¹³ [The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.](#)

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Comprehensive building efficiency improvements will reduce load and may lead to downsizing of space conditioning equipment. To properly account for these interactive effects, energy modeling should be performed and the results should be used for savings attribution in place of savings algorithms shown here. Effects of HVAC downsizing can be attributed to either weatherization or HVAC, but not both.

Definition of Baseline Condition

The baseline condition for the Time of Sale measure is an Air Source Heat Pump split system that meets the minimum Federal standards defined above.

The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline of the same equipment type for the remainder of the new, efficient equipment measure life as provided in the table below.

Note that to be characterized as early replacement, the age of the unit must not exceed the measure life of 18 years.

Early Retirement/Replacement Baseline Efficiencies			
Existing Equipment Type	HSPF	SEER Rating	EER Rating
ASHP	8.2	14	11.8
Electric Resistance and Central AC	3.41	14	11.0

Definition of Efficient Condition

The efficient condition is an Air Source Heat Pump split system that meets the ENERGY STAR standards defined above or other specifications as determined by the programs.

Annual Energy Savings Algorithm

Annual energy savings is the sum of heating and cooling savings.

SEER, EER, and HSPF should be replaced with SEER2, EER2, and HSPF2 ratings in the below equations where appropriate.

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Time of Sale:

$$\Delta kWH = EFLH_{cool} \times \frac{(BTUHC_{exist} / SEER_{base}) - (BTUHC_{ee} / SEER_{ee})}{1000} \\ + EFLH_{heat} \times \frac{(BTUHH_{exist} / HSPF_{base}) - (BTUHH_{ee} / HSPF_{ee})}{1000}$$

Early replacement²¹⁴:

ΔkWH for remaining life of existing unit:

²¹⁴ The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

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$$\Delta kWH = EFLH_{cool} \times \frac{(BTUHC_{exist} / SEER_{exist}) - (BTUHC_{ee} / SEER_{ee})}{1000} + EFLH_{heat} \times \frac{(BTUHH_{exist} / HSPF_{exist}) - (BTUHH_{ee} / HSPF_{ee})}{1000}$$

ΔkWH for remaining measure life:

$$\Delta kWH = EFLH_{cool} \times \frac{(BTUHC_{exist} / SEER_{basereplace}) - (BTUHC_{ee} / SEER_{ee})}{1000} + EFLH_{heat} \times \frac{(BTUHH_{exist} / HSPF_{basereplace}) - (BTUHH_{ee} / HSPF_{ee})}{1000}$$

Where:

<i>EFLH_{cool}</i>	= Full Load Cooling Hours
	= Dependent on location as below:
Location	FLH _{cool}
Wilmington, DE	719 ²¹⁵

²¹⁵ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (744 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

Baltimore, MD	744 ²¹⁶
Washington, DC	935

- BTUHC_{exist}*

= Cooling capacity of existing Air Source Heat Pump (tons x 12,000BTU/hr)
= Actual
- BTUHC_{ee}*

= Cooling capacity of new, efficient Air Source Heat Pump (tons x 12,000BTU/hr)
= Actual
- SEER_{base}*

= Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump
= 15²¹⁷
- SEER_{exist}*

= Seasonal Energy Efficiency Ratio of existing cooling system (kBTU/kWh)
= Use actual SEER rating where it is possible to measure or reasonably estimate. If not, assume the following dependent on type of existing cooling system:

²¹⁶ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31 2013) Residential HVAC Program.” April 4, 2014, Table 30, page 48.

²¹⁷ Minimum federal standard, <https://www.seer2.com/region-southeast.html>

Existing Cooling System	SEER _{exist} ²¹⁸
Air Source Heat Pump or Central AC	11
No central cooling ²¹⁹	Make '1/SEER _{exist} ' = 0

SEER_{ee} = Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump
= Actual

SEER_{basereplace} = Baseline Seasonal Energy Efficiency Ratio of same, new equipment type as existing:

Existing Equipment Type	SEER Rating
ASHP	15 ₄
Central AC or no replaced cooling	15 ₄

²¹⁸ Based on Itron and Cadmus unpublished analysis of standard efficiency units by age of unit from Energy Information Administration, Residential Energy Consumption Survey, 2015, AHRI historical shipments data (<http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx>), and Energy Star historical shipments data (https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?52f9-67a), and mortality curve assumptions drawn from Cory Welch, Estimating the Useful Life of Residential Appliances, ACEEE Summer Study 2010 paper (<http://aceee.org/files/proceedings/2010/data/papers/1977.pdf>)

²¹⁹ If there is no central cooling in place but the incentive encourages installation of a new ASHP with cooling, the added cooling load should be subtracted from any heating benefit.

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FLHheat = Full Load Heating Hours
= Dependent on location as below:

Location	FLHheat
Wilmington, DE	935 ²²⁰
Baltimore, MD	866 ²²¹
Washington, DC	822

BTUHH_{exist} = Heating capacity of existing Air Source Heat Pump (tons x 12,000BTU/hr)
= Actual

BTUHH_{ee} = Heating capacity of new, efficient Air Source Heat Pump (tons x 12,000BTU/hr)
= Actual

²²⁰ Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E’s full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator.

(https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls)
²²¹ Based on average of 5 utilities, two program years, in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

HSPFbase

= Heating Seasonal Performance Factor of baseline Air Source Heat
= 8.8²²²

HSPFexist

= Heating System Performance Factor²²³ of existing heating system (kBtu/kWh)

= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available, use reference the table below:

Air Source Heat Pump Federal Efficiency Standards	
Age	HSPF
Before 2006	6.8
2006 - 2014	7.7
2015 - ~~present~~ 2022	8.2
2023 - present	8.8
Electric Resistance	3.41 ²²⁴

²²² Minimum Federal Standard

²²³ HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within zone 4 which encompasses all of the Mid Atlantic region. There should therefore be no reason to adjust the rated HSPF for geographical/climate variances.

²²⁴ Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF

HSPFee

= Heating Seasonal Performance Factor of efficient Air Source Heat Pump
= Actual

HSPFbasereplace

= Baseline Heating System Performance Factor of same, new equipment type as existing (kBTU/kWh)

Existing Equipment Type	HSPF
ASHP	8.2
Electric Resistance and Central AC	3.41

Illustrative example – do not use as default assumption
Time of Sale example: a 3-ton unit with a SEER rating of 15 and HSPF of 8.5 upgraded from lower efficiency to higher, with an equivalent sized unit in Baltimore, MD:

$$\begin{aligned} \Delta kWh &= 744 \times ((36,000/14) - (36,000/15))/1,000 \\ &\quad + 866 \times ((36,000/7.7) - (36,000/8.5))/1,000 \\ &= 509 \text{ kWh} \end{aligned}$$

Early Replacement example where there is a “right-sizing” adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): a 2-ton heat pump with a SEER rating of 15 and HSPF of 8.5 in Baltimore, MD is installed replacing an existing working 3 ton Central AC system with a SEER rating of 11 and electric resistance heating:

$$\begin{aligned}\Delta \text{kWh (remaining life)} &= \\ 744 \times ((36,000/11) - (24,000/15))/1,000 \\ + 866 \times ((36,000/3.41) - (24,000/8.5))/1,000 \\ &= 7,942 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta \text{kWh (through end of life)} &= \\ 744 \times ((36,000/14) - (24,000/15))/1,000 \\ + 866 \times ((36,000/3.41) - (24,000/8.5))/1,000 \\ &= 7,420 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta \text{kW} = \frac{(BTUHC_{exist} \times 1 / EER_{base}) - (BTUHC_{ee} \times 1 / EER_{ee})}{1000 \times CF}$$

Early replacement:

 ΔkW for remaining life of existing unit:

$$\Delta \text{kW} = \frac{(BTUHC_{exist} \times 1 / EER_{exist}) - (BTUHC_{ee} \times 1 / EER_{ee})}{1000 \times CF}$$

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ΔkW for remaining measure life:

$$\Delta kW = \frac{(BTUHC_{exist} \times 1 / EER_{base\ replace}) - (BTUHee \times 1 / EER_{ee})}{1000 \times CF}$$

Where:

EER_{base} = Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump
 = ~~12.34~~²²⁵

EER_{exist} = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)
 = Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:
 $EER = (-0.02 * SEER^2) + (1.12 * SEER)$ ²²⁶
 If SEER rating unavailable, use:

²²⁵ The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (154) and equals EER ~~12.34~~⁸. To perform this calculation we are using this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$ (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

²²⁶ From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

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Existing Cooling System	EERexist
Air Source Heat Pump or Central AC	9.9
No central cooling ²²⁷	Make '1/EERexist' = 0

EER_{ee} = Energy Efficiency Ratio (EER) of Efficient Air Source Heat Pump
= Actual

EER_{basereplace} = Baseline Energy Efficiency Ratio of same, new equipment type as existing:

Existing Equipment Type	EER Rating
ASHP	11.8
Electric Resistance and Central AC	11.8

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69²²⁸

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather

²²⁷ If there is no central cooling in place but the incentive encourages installation of a new ASHP with cooling, the added cooling load should be subtracted from any heating benefit.
²²⁸ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

$$= 0.66^{229}$$

Illustrative example – do not use as default assumption

Time of Sale example: a 3-ton unit with EER rating of 11.8 upgraded from lower efficiency to higher, by a 2-ton unit with an EER of 12.5 in Baltimore, MD:

$$\begin{aligned}\Delta kW_{SSP} &= ((36,000 \times 1/11.8) - (24,000 \times 1/12.5))/1,000 \times 0.69 \\ &= 0.78kW\end{aligned}$$

Early Replacement example where there is a “right-sizing” adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): a 2-ton unit with an EER rating of 12.5 in Baltimore, MD is installed replacing an existing working 3-ton Central AC system with an EER rating of 9.9 and electric resistance heating:

$$\begin{aligned}\Delta kW_{SSP} &= ((36,000 \times 1/9.9) - (24,000 \times 1/12.5))/1,000 \times 0.69 \\ &= 1.18 kW\end{aligned}$$

ΔkW for remaining measure life (through end of life):

²²⁹ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

$$\Delta kW_{SSP} = ((36,000 \times 1/11.8) - (24,000 \times 1/12.5))/1,000 \times 0.69$$
$$= 0.78kW$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental costs per ton for this measure are provided below:²³⁰

SEER	Time of Sale	Early Replacement
16	\$394	\$943
17	\$591	\$1,140
18	\$788	\$1,337
19	\$985	\$1,535

²³⁰ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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SEER	Time of Sale	Early Replacement
20	\$1,182	\$1,732
21	\$1,379	\$1,929

Measure Life

The measure life is assumed to be 18 years²³¹.

Remaining life of existing equipment is assumed to be 6 years²³² unless otherwise known.

Operation and Maintenance Impacts

n/a

²³¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007 https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

²³² Assumed to be one third of the effective useful life.

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Packaged Terminal Air Conditioners (PTAC) and Heat Pumps (PTHP)

Unique Measure Code(s): RS_HV_TOS_PTAC_0518, RS_HV_ER_PTAC_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure documents savings associated with the installation of new packaged terminal AC and packaged terminal heat pumps exceeding baseline efficiency criteria in place of an existing system or a new standard efficiency system of the same capacity. This measure does not cover ductless mini-split units. This measure applies to time of sale, new construction, and early replacement opportunities, primarily for multifamily buildings.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a new system meeting minimum efficiency standards as presented in the 2018 International Energy Conservation Code (IECC 2018) (see table “Baseline Efficiencies by System Type and Unit Capacity” below) or federal standards where more stringent than local energy codes.

Early Replacement: The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.

Definition of Efficient Condition

The efficient condition is a PTAC or PTHP system of the same type as the baseline system exceeding baseline efficiency levels.

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Baseline Efficiencies by System Type and Unit Capacity

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards) ²³³
Packaged Terminal Air Conditioners^{234,235}		
All Capacities	New Construction (Standard Size)	14.0 – (0.300 * Cap/1000) EER
All Capacities	Replacement (Non-Standard Size)	10.9 – (0.213 * Cap/1000) EER
Packaged Terminal Heat Pumps^{236,237}		
All Capacities	New Construction (Standard Size)	14.0 – (0.300 * Cap/1000) EER 3.7 – (0.052 * Cap/1000) OP

²³³ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.96 (2021). Consistent with IECC 2018 in all cases except for PTHP new construction COP which is calculated as “3.2 - (0.026 x Cap/1000)”.

²³⁴ Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

²³⁵ “Cap” = The rated cooling capacity of the project in BTU/h. If the unit’s capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit’s capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations.

²³⁶ Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

²³⁷ “Cap” = The rated cooling capacity of the project in BTU/h. If the unit’s capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit’s capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations.

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards) ²³³
All Capacities	Replacement (Non-Standard Size)	10.8 – (0.213 * Cap/1000) EER 2.9 – (0.026 * Cap/1000) COP

Notes: 1) All cooling mode efficiency ratings in the table above assume electric resistance heating section type (or none). Subtract 0.2 from each baseline efficiency rating value if unit has heating section other than electric resistance.

Annual Energy Savings Algorithm
Packaged Terminal Air Conditioners (PTACs)

Time of Sale:

For all PTACs, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * EFLH_c$$

Early Replacement²³⁸:

For all PTACs, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

²³⁸ The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

ΔkWh for remaining life of existing unit (i.e., measure life less the age of the existing equipment):

$$= (BTU/h/1000) * ((1/EER_{EXIST}) - (1/EER_{EE})) * EFLH_C.$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (BTU/h/1000) * ((1/EER_{BASE}) - (1/EER_{EE})) * EFLH_C.$$

Packaged Terminal Heat Pumps (PTHPs)

Time of Sale:

For all PTHPs, the energy savings are calculated using the Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EER_{BASE}) - (1/EER_{EE})) * EFLH_C.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COP_{BASE}) - (1/COP_{EE})) * EFLH_H.$$

Early Replacement²³⁹:

For all PTHPs, the energy savings are calculated using the Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

²³⁹ The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

ΔkWh for remaining life of existing unit (i.e., measure life less the age of the existing equipment):

$$\begin{aligned}\Delta kWh &= \Delta kWh_{COOL} + \Delta kWh_{HEAT} \\ \Delta kWh_{COOL} &= (BTU/h_{COOL}/1000) * ((1/EER_{EXIST}) - (1/EER_{EE})) * EFLH_C \\ \Delta kWh_{HEAT} &= (BTU/h_{HEAT}/3412) * ((1/COP_{EXIST}) - (1/COP_{EE})) * EFLH_H\end{aligned}$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$\begin{aligned}\Delta kWh &= \Delta kWh_{COOL} + \Delta kWh_{HEAT} \\ \Delta kWh_{COOL} &= (BTU/h_{COOL}/1000) * ((1/EER_{BASE}) - (1/EER_{EE})) * EFLH_C \\ \Delta kWh_{HEAT} &= (BTU/h_{HEAT}/3412) * ((1/COP_{BASE}) - (1/COP_{EE})) * EFLH_H\end{aligned}$$

Where:

ΔkWh_{COOL}	= Annual cooling season electricity savings (kWh).
ΔkWh_{HEAT}	= Annual heating season electricity savings (kWh).
BTU/h_{COOL}	= Cooling capacity of equipment in BTU/hour. = Actual Installed.
BTU/h_{HEAT}	= Heating capacity of equipment in BTU/hour. = Actual Installed.
$SEER_{EE}$	= SEER of efficient unit. = Actual Installed.
$SEER_{BASE}$	= SEER of baseline unit.

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	<i>= Based on federal standards for the installed capacity. See table above.</i>
SEEREXIST	<i>= SEER of the existing unit.</i>
	<i>= Actual.</i>
HSPFEE	<i>= HSPF of efficient unit.</i>
	<i>= Actual Installed.</i>
HSPFBASE	<i>= HSPF of baseline unit.</i>
	<i>= Based on federal standards for the installed capacity. See table above.</i>
HSPFEXIST	<i>= HSPF of the existing unit.</i>
	<i>= Actual.</i>
COPEE	<i>= COP of efficient unit.</i>
	<i>= Actual Installed.</i>
COPBASE	<i>= COP of baseline unit.</i>
	<i>= Based on federal standards for the installed capacity. See table above.</i>
COPEXIST	<i>= COP of the existing unit.</i>
	<i>= Actual.</i>
EERBASE	<i>= EER of baseline unit.</i>
	<i>= Based on federal standards for the installed capacity. See table above.</i>
EEREE	<i>= EER of efficient unit (If the actual EER is unknown, it may be approximated by using the following equation: $EER = SEER/1.2$)</i>
	<i>= Actual installed.</i>
EEREXIST	<i>= EER of existing unit.</i>
	<i>= Actual.</i>
3412	<i>= Conversion factor (BTU/kWh).</i>

EFLH_C = Full load cooling hours.²⁴⁰
= If actual full load cooling hours are unknown, see table “Full Load Cooling Hours by Location and Building Type” below.
Otherwise, use site specific full load cooling hours information.

EFLH_H = Full load heating hours.
= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” below.
Otherwise, use site specific full load heating hours information.

EFLH_C = Full load cooling hour value (Table below)
= Dependent on location as below:

Location	EFLH _C
Wilmington, DE	719 ²⁴¹

²⁴⁰ From U.S. DOE. 2013. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*: “Although the EFLH is calculated with reference to a peak kW derived from EER, it is acceptable to use these EFLH with SEER or IEER. Some inconsistency occurs in using full-load hours with efficiency ratings measured at part loading, but errors in calculation are thought to be small relative to the expense and complexity of developing hours-of-use estimates precisely consistent with SEER and IEER.”

²⁴¹ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (744 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

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<i>Baltimore, MD</i>	744 ²⁴²
<i>Washington, DC</i>	935

EFLH_H = Full load heating hour value (Table below)

<i>Location</i>	<i>EFLHh</i>
<i>Wilmington, DE</i>	935 ²⁴³
<i>Baltimore, MD</i>	866 ²⁴⁴
<i>Washington, DC</i>	822

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta kW = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * CF.$$

Early Replacement:

ΔkW for remaining life of existing unit (i.e., measure life less the age of the existing equipment):

²⁴² Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31 2013) Residential HVAC Program.” April 4, 2014, Table 30, page 48.

²⁴³ Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E’s full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator.

(http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

²⁴⁴ Based on average of 5 utilities, two program years, in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

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$$= (\text{BTU}/\text{h}_{\text{COOL}}/1000) * ((1/\text{EER}_{\text{EXIST}}) - (1/\text{EER}_{\text{EE}})) * \text{CF}.$$

ΔkW for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (\text{BTU}/\text{h}_{\text{COOL}}/1000) * ((1/\text{EER}_{\text{BASE}}) - (1/\text{EER}_{\text{EE}})) * \text{CF}.$$

Where:

CF_{PJM}

= PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather

= 0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.²⁴⁵

CF_{SSP}

= Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

= 0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.²⁴⁶

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental costs for time of sale and early replacement units are provided in the tables below.²⁴⁷ Prescribed values vary depending on the current

²⁴⁵ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011.

²⁴⁶ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011.

²⁴⁷ Default incremental costs assumptions for water- and evaporatively-cooled ACs, PTACs, and PTHPs will be addressed in subsequent versions of the TRM, when available. In the interim, incremental costs for these equipment types should be determined on a site-specific basis.

building code, the date of installation, and whether the baseline condition is time of sale or early replacement.²⁴⁸

Measure Life

The measure life is assumed to be 15 years.²⁴⁹

Operation and Maintenance Impacts

n/a

Operation and Maintenance Impacts

n/a

²⁴⁸ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

²⁴⁹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>.

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Duct Sealing

Unique Measure Code: RS_HV_RF_DCTSLG_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure is the sealing of ducts using mastic sealant, aerosol or UL-181 compliant duct sealing tape.

Three methodologies for evaluating the savings associated with sealing the ducts are provided. The first method is provided only as a tool for prescreening potential measures involving a careful visual inspection of the duct work, followed by two further methods that require the use of a blower door either of which can be used to evaluate savings.

1. **Feasibility Evaluation of Distribution Efficiency** – this methodology should **not be used for claiming savings** but can be a useful tool to help evaluate the potential from duct sealing. It requires evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table';

<http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>

- a. Percentage of duct work found within the conditioned space
- b. Duct leakage evaluation
- c. Duct insulation evaluation

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2. Modified Blower Door Subtraction – this technique is described in detail on p44 of the Energy Conservatory Blower Door Manual; <http://www.energyconservatory.com/download/bdmanual.pdf>
It involves performing a whole house depressurization test and repeating the test with the ducts excluded.

3. Duct Blaster Testing - as described in RESNET Test 803.7 http://www.resnet.us/standards/DRAFT_Chapter_8_July_22.pdf
This involves using a blower door to pressurize the house to 25 Pascals and pressurizing the duct system using a duct blaster to reach equilibrium with the inside. The air required to reach equilibrium provides a duct leakage estimate.

This is a retrofit measure. Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Attempt should be made to account for this interaction where the measures occur in the same home within the same program period.

Definition of Baseline Condition

The existing baseline condition is leaky duct work within the unconditioned space in the home.

Definition of Efficient Condition

The efficient condition is sealed duct work throughout the unconditioned space in the home.

Annual Energy Savings Algorithm

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SEER, EER, and HSPF should be replaced with SEER2, EER2, and HSPF2 ratings in the below equations where appropriate.

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Methodology 1: Feasibility Evaluation of Distribution Efficiency (not for claiming savings)

Total Annual Savings:

$$\Delta \text{kWh} = \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}$$

Estimate of Cooling savings from reduction in Air Conditioning Load:

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute “Distribution Efficiency Look-Up Table”

$$\Delta \text{kWh}_{\text{cooling}} = (((DE_{\text{after}} - DE_{\text{before}}) / DE_{\text{after}})) * FLH_{\text{cool}} * \text{BTUH}) / 1,000 / \eta_{\text{Cool}}$$

Where:

- DE_{after} = Distribution Efficiency after duct sealing
- DE_{before} = Distribution Efficiency before duct sealing
- FLH_{cool} = Full Load Cooling Hours
- = Dependent on location as below:

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<i>Location</i>	<i>FLHcool</i>
<i>Wilmington, DE</i>	<i>524²⁵⁰</i>
<i>Baltimore, MD</i>	<i>542²⁵¹</i>
<i>Washington, DC</i>	<i>681</i>

BTUH = Size of equipment in BTUh (note 1 ton = 12,000BTUh)
= Actual
ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available, use²⁵²:

<i>Equipment Type</i>	<i>Age of Equipment</i>	<i>SEER Estimate</i>
<i>Central AC</i>	<i>Before 2006</i>	<i>10</i>
	<i>After 2006 2006-2022</i>	<i>13</i>
	<i>2023 to present</i>	<i>15</i>
<i>Heat Pump</i>	<i>Before 2006</i>	<i>10</i>
	<i>2006-2014</i>	<i>13</i>
	<i>2015--2022 ~~on~~</i>	<i>14</i>

²⁵⁰ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

²⁵¹ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

²⁵² These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

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	2023 to present	15

Illustrative example – do not use as default assumption
Duct sealing in a house in Wilmington DE, with 3-ton SEER 11 central air conditioning and the following duct evaluation results:

DE_{before} = 0.80
DE_{after} = 0.90

Energy Savings:

$$\Delta \text{kWh}_{\text{Cooling}} = ((0.90 - 0.80) / 0.90) * 524 * 36,000 / 1,000 / 11$$
$$= 191 \text{ kWh}$$

Estimate of Heating savings for homes with electric heat (Heat Pump of resistance):

$$\text{kWh}_{\text{Heating}} = (((((\text{DE}_{\text{after}} - \text{DE}_{\text{before}}) / \text{DE}_{\text{after}})) * \text{FLH}_{\text{heat}} * \text{BTUH}) / 1,000,000 / \eta_{\text{Heat}}) * 293.1$$

Where:
FLH_{heat} = Full Load Heating Hours
= Dependent on location as below:

Location	FLH _{heat}

Wilmington, DE	935 ²⁵³
Baltimore, MD	866 ²⁵⁴
Washington, DC	822

BTUH = Size of equipment in BTUh (note 1 ton = 12,000BTUh)

= Actual

η_{Heat} = Efficiency in COP of Heating equipment

= actual. If not available, use²⁵⁵:

System Type	Age of Equipment	HSPF Estimate	COP Estimate
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015-2022- ~~on~~	8.2	2.40
	2023 onward	8.8	2.58
Resistance	n/a	n/a	1.00

Illustrative example – do not use as default assumption

²⁵³ Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator.

(http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)
²⁵⁴ Based on average of 5 utilities, two program years, in Maryland from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program." April 4, 2014, table 30, page 48.

²⁵⁵ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

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Duct sealing in a 2.5 COP heat pump heated house in Baltimore, MD with the following duct evaluation results:

$$\begin{aligned} DE_{\text{before}} &= 0.80 \\ DE_{\text{after}} &= 0.90 \end{aligned}$$

Energy Savings:

$$\begin{aligned} \Delta kWh_{\text{Heating}} &= (((0.90 - 0.80)/0.90) * 866 * 36,000) / 1,000,000 \\ &\quad / 2.5 * 293.1 \\ &= 406 \text{ kWh} \end{aligned}$$

Methodology 2: Modified Blower Door Subtraction

Total Annual Savings:

$$\Delta kWh = \Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}}$$

Claiming Cooling savings from reduction in Air Conditioning Load:

- a. Determine Duct Leakage rate before and after performing duct sealing:

$$\text{Duct Leakage (CFM50}_{\text{DL}}) = (\text{CFM50}_{\text{Whole House}} - \text{CFM50}_{\text{Envelope Only}}) * \text{SCF}$$

Where:

$$\text{CFM50}_{\text{Whole House}} = \text{Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential}$$

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<i>CFM50_{Envelope Only}</i>	<i>= Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.</i>
<i>SCF</i>	<i>= Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.</i>

- b. Calculate duct leakage reduction, convert to CFM25_{DL}²⁵⁶ and factor in Supply and Return Loss Factors

Duct Leakage Reduction ($\Delta\text{CFM25}_{\text{DL}}$) = (Pre CFM50_{DL} – Post CFM50_{DL}) * 0.64 * (SLF + RLF)

Where :

SLF = Supply Loss Factor
= % leaks sealed located in Supply ducts * 1²⁵⁷

²⁵⁶ 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the “Can’t Reach Fifty” factor for CFM25; see Energy Conservatory Blower Door Manual).

²⁵⁷ Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from

<http://www.energyconservatory.com/download/dbmanual.pdf>

RLF

Default = 0.5²⁵⁸

= Return Loss Factor

= % leaks sealed located in Return ducts * 0.5²⁵⁹

Default = 0.25²⁶⁰

c. Calculate Energy Savings:

$$\Delta kWh_{cooling} = ((\Delta CFM_{25_{DL}}) / (Capacity * 400)) * FLH_{cool} * BTUH / 1000 / \eta_{Cool}$$

Where:

$\Delta CFM_{25_{DL}}$

= Duct leakage reduction in CFM25

Capacity

= Capacity of Air Cooling system (tons)

400

= Conversion of Capacity to CFM (400CFM / ton)

FLHcool

= Full Load Cooling Hours

= Dependent on location as below:

Location	FLHcool

²⁵⁸ Assumes 50% of leaks are in supply ducts.

²⁵⁹ Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than “average” (e.g. pulling return air from a super-heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space). More information provided in “Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements” from <http://www.energyconservatory.com/download/dbmanual.pdf>

²⁶⁰ Assumes 50% of leaks are in return ducts.

Wilmington, DE	524 ²⁶¹
Baltimore, MD	542 ²⁶²
Washington, DC	681

BTUH = Size of equipment in BTUh (note 1 ton = 12,000BTUh)
= Actual

η_{Cool} = Efficiency in SEER of Air Conditioning equipment
= actual. If not available, use²⁶³:

Equipment Type	Age of Equipment	SEER Estimate
<u>Central AC</u>	<u>Before 2006</u>	<u>10</u>
	<u>2006-2022</u>	<u>13</u>
	<u>2023 to present</u>	<u>15</u>
<u>Heat Pump</u>	<u>Before 2006</u>	<u>10</u>
	<u>2006-2014</u>	<u>13</u>
	<u>2015-2022</u>	<u>14</u>
	<u>2023 to present</u>	<u>15</u>

²⁶¹ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPOWER average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

²⁶² Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

²⁶³ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

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Equipment Type	Age of Equipment	SEER Estimate
Central AC	Before 2006	10
	After 2006	13
Heat Pump	Before 2006	10
	2006–2014	13
	2015 on	14

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Illustrative example – do not use as default assumption
Duct sealing in a house in Wilmington, DE with 3-ton, SEER 11 central air conditioning and the following blower door test results:

Before:

CFM50_{Whole House}

CFM50_{Envelope Only}

House to duct pressure

= 4,800 CFM50

= 4,500 CFM50

= 45 Pascals

= 1.29 SCF (Energy Conservatory look up table)

After:

CFM50_{Whole House}

CFM50_{Envelope Only}

House to duct pressure

= 4,600 CFM50

= 4,500 CFM50

= 43 Pascals

= 1.39 SCF (Energy Conservatory look up table)

Duct Leakage at CFM50:

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$$\begin{aligned}\text{CFM50}_{\text{DL before}} &= (4,800 - 4,500) * 1.29 \\ &= 387 \text{ CFM50}\end{aligned}$$

$$\begin{aligned}\text{CFM50}_{\text{DL after}} &= (4,600 - 4,500) * 1.39 \\ &= 139 \text{ CFM50}\end{aligned}$$

Duct Leakage reduction at CFM25:

$$\begin{aligned}\Delta\text{CFM25}_{\text{DL}} &= (387 - 139) * 0.64 * (0.5 + 0.25) \\ &= 119 \text{ CFM25}\end{aligned}$$

Energy Savings:

$$\begin{aligned}\Delta\text{kWh}_{\text{Cooling}} &= ((119 / (3 * 400)) * 524 * 36,000) / 1,000 / 11 \\ &= 170 \text{ kWh}\end{aligned}$$

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta\text{kWh}_{\text{Heating}} = (((\Delta\text{CFM25}_{\text{DL}} / (\text{Capacity} * 400)) * \text{FLHheat} * \text{BTUH}) / 1,000,000 / \eta_{\text{Heat}}) * 293.1$$

Where:

- $\Delta\text{CFM25}_{\text{DL}}$ = Duct leakage reduction in CFM25
- Capacity = Capacity of Air Cooling system (tons)
- 400 = Conversion of Capacity to CFM (400CFM / ton)
- FLHheat = Full Load Heating Hours
- = Dependent on location as below:

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Location	FLHheat
Wilmington, DE	935 ²⁶⁴
Baltimore, MD	866 ²⁶⁵
Washington, DC	822

BTUH = Size of equipment in BTUh (note 1 ton = 12,000BTUh)
 = Actual
 η_{Heat} = Efficiency in COP of Heating equipment
 = actual. If not available, use²⁶⁶.

System Type	Age of Equipment	HSPF Estimate	COP Estimate
Heat Pump	Before 2006	6.8	2.00
	2006-2014	7.7	2.26
	2015-2022-on	8.2	2.40
	2023 onward	8.8	2.58
Resistance	n/a	n/a	1.00

²⁶⁴ Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator.

(http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)
²⁶⁵ Based on average of 5 utilities, two program years, in Maryland from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program." April 4, 2014, table 30, page 48.

²⁶⁶ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

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Illustrative example – do not use as default assumption

Duct sealing in a 3-ton 2.5 COP heat pump heated house in Baltimore, MD with the blower door results described above:

$$\begin{aligned}\Delta\text{kWh}_{\text{Heating}} &= (((119 / (3 * 400)) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1 \\ &= 362 \text{ kWh}\end{aligned}$$

Methodology 3: Duct Blaster Testing

Total Annual Savings:

$$\Delta\text{kWh} = \Delta\text{kWh}_{\text{cooling}} + \Delta\text{kWh}_{\text{heating}}$$

Claiming Cooling savings from reduction in Air Conditioning Load:

$$\Delta\text{kWh}_{\text{cooling}} = (((\text{Pre\_CFM25} - \text{Post\_CFM25}) / (\text{Capacity} * 400)) * \text{FLH}_{\text{cool}} * \text{BTUH}) / 1000 / \eta_{\text{Cool}}$$

Where:

Pre_CFM25 = Duct leakage in CFM25 as measured by duct blaster test before sealing

Post_CFM25 = Duct leakage in CFM25 as measured by duct blaster test after sealing

All other variables as provided above.

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Illustrative example – do not use as default assumption

Duct sealing in a house in Wilmington, DE with 3-ton, SEER 11 central air conditioning and the following duct blaster test results:

$$\begin{aligned}
 Pre\_CFM25 &= 220 \text{ CFM25} \\
 Post\_CFM25 &= 80 \text{ CFM25} \\
 \Delta kWh_{Cooling} &= (((220 - 80) / (3 * 400)) * 524 * 36,000) / 1,000 / 11 \\
 &= 200 \text{ kWh}
 \end{aligned}$$

Claiming Heating savings for homes with electric heat (Heat Pump):

$$\Delta kWh_{Heating} = (((Pre\_CFM25 - Post\_CFM25) / (Capacity * 400)) * FLH_{heat} * BTUH) / 1,000,000 / \eta_{Heat} * 293.1$$

Where:

All other variables as provided above.

Illustrative example – do not use as default assumption

Duct sealing in a 3-ton 2.5 COP heat pump heated house in Baltimore, MD with the duct blaster results described above:

$$\Delta kWh_{Heating} = (((220 - 80) / (3 * 400)) * 866 * 36,000) / 1,000,000 / 2.5 * 293.1$$

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= 426 kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh_{cooling} / FLH_{cool} * CF$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69²⁶⁷

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.66²⁶⁸

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

Methodology 1: Feasibility Evaluation of Distribution Efficiency (not for claiming savings)

$\Delta MMBTU_{fossil\ fuel} = (((DE_{after} - DE_{before}) / DE_{after})) * FLH_{heat} * BTUH) / 1,000,000 / \eta_{Heat}$

²⁶⁷ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

²⁶⁸ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

Where:

DE_{after} = Distribution Efficiency after duct sealing
 DE_{before} = Distribution Efficiency before duct sealing
 FLH_{heat} = Full Load Heating Hours
= 620²⁶⁹
 $BTUH$ = Capacity of Heating System
= Actual
 η_{Heat} = Efficiency of Heating equipment
= Actual²⁷⁰. If not available, use 84%²⁷¹.

Illustrative example – do not use as default assumption
Duct sealing in a fossil fuel heated house with a 100,000BTUh, 80% AFUE natural gas furnace, with the following duct evaluation results:

DE_{before} = 0.80
 DE_{after} = 0.90
Energy Savings:
 $\Delta MMBTU = ((0.90 - 0.80) / 0.90) * 620 * 100,000 / 1,000,000 / 0.80$

²⁶⁹ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

²⁷⁰ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

²⁷¹ The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.

= 8.6 MMBTU

Methodology 2: Modified Blower Door Subtraction

$$\Delta \text{MMBTU} = (((\Delta \text{CFM}_{25\text{DL}} / (\text{BTUH} * 0.0126)) * \text{FLHheat} * \text{BTUH}) / 1,000,000) / \eta \text{Heat}$$

Where:

- $\Delta \text{CFM}_{25\text{DL}}$ = Duct leakage reduction in CFM25
- BTUH = Capacity of Heating System (BTUh)
= Actual
- 0.0126 = Conversion of Capacity to CFM (0.0126CFM / BTUh)²⁷²
- FLHheat = Full Load Heating Hours
= 620²⁷³
- ηHeat = Efficiency of Heating equipment

²⁷² Based on Natural Draft Furnaces requiring 100 CFM per 10,000 BTU, Induced Draft Furnaces requiring 130CFM per 10,000BTU and Condensing Furnaces requiring 150 CFM per 10,000 BTU (rule of thumb from http://contractingbusiness.com/enewsletters/cb_imp_43580/). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 32% of furnaces purchased in Maryland were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 126 per 10,000BTU or 0.0126/BTU.

²⁷³ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

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= Actual²⁷⁴. If not available, use 84%²⁷⁵.

Illustrative example – do not use as default assumption

Duct sealing in a house with a 100,000BTUh, 80% AFUE natural gas furnace and with the blower door results described above:

Energy Savings:

$$\begin{aligned}\Delta\text{MMBTU} &= (((119 / (100,000 * 0.0126)) * 620 * 100,000) / 1,000,000 / 0.80 \\ &= 7.3 \text{ MMBTU}\end{aligned}$$

Methodology 3: Duct Blaster Testing

$$\Delta\text{MMBTU} = (((\text{Pre\_CFM25} - \text{Post\_CFM25}) / (\text{BTUH} * 0.0126)) * \text{FLHheat} * \text{BTUH}) / 1,000,000 / \eta_{\text{Heat}}$$

Where:

All variables as provided above

Illustrative example – do not use as default assumption

Duct sealing in a house with a 100,000BTUh, 80% AFUE natural gas furnace and with the duct blaster results described above:

Energy Savings:

²⁷⁴ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

²⁷⁵ The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.

$$\begin{aligned}\Delta\text{MMBTU} &= (((220 - 80 / (100,000 * 0.0126)) * 620 * 100,000) / 1,000,000 / \\ &0.80 \\ &= 8.6 \text{ MMBTU}\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual labor and material cost.

Measure Life

The measure life is assumed to be 20 years²⁷⁶.

Operation and Maintenance Impacts

n/a

²⁷⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.pdf>

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Ductless Mini-Split Heat Pump

Unique Measure Code: RS_HV_TOS_MSHP_0518, RS_HV_EREP_ASHP_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of new ENERGY STAR rated ductless “mini-split” heat pump(s) (DMSHP). A ductless mini-split heat pump (DMSHP) is a type of heat pump with an outdoor condensing unit connected via refrigerant line to one or more indoor evaporator coils. Ductless mini-split heat pumps deliver cooling at the same or higher efficiency as standard central AC units, but can also deliver heat. Further, since the units do not require ductwork, they avoid duct losses.

This measure could be installed in either an existing or in a new home and the characterization is designed to allow the calculation of the impact on electric and/or gas consumption following the installation of a DHP system. The characterization requires that the program implementer perform a custom calculation to determine how much existing and supplemental heating and/or cooling load the DHP will replace based on a combination of billing data, the percentage of conditioned space covered by the DMSHP, the existing equipment and its hours of operation, proposed hours of operation, and the size of the conditioned space. Where possible, this should be treated as a custom measure, due to the number of variables needed, including usage patterns and types of baseline systems.

Definition of Baseline Condition

The baseline condition for early replacement is the existing heating and cooling (if applicable) systems within the home. If cooling equipment is not previously present,

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it is presumed that some type of cooling equipment would have been installed and the time of sale baseline described next should be used for the cooling baseline assumption.

By January 1, 2023, all heat pumps will be subject to new national minimum efficiency levels. However, Existing 14.0 SEER heat pumps built prior to January 1, 2023 may still be sold and installed on or after January 1, 2023 in all regions. While single-packaged heat pumps may remain at 13.4 SEER2 (14.0 SEER) and 6.7 HSPF2 (8.0 HSPF), all split-system heat pumps must increase to 14.3 SEER2 (15.0 SEER) and 7.5 HSPF2 (8.8 HSPF). These units will need to adhere to the new testing measures and meet SEER2 rating requirements.

The baseline condition in time of sale / new construction is a standard-efficiency ductless unit meeting the following efficiency standards²⁷⁷:

Manufactured Prior to 1/1/2023			Manufactured After 1/1/2023		
SEER ₂	EER ₂	HSPF ₂	SEER ₂	EER ₂	HSPF ₂
15.4	12.38.5 ²⁷⁸	8.82	14.3	11.95	7.5

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Definition of Efficient Condition

The efficient condition is an ENERGY STAR V6.1²⁷⁹ ductless heat pump exceeding all of the following efficiency standards; 15.2 SEER₂, 12.511.71.7 EER₂, 7.88.5 HSPF₂.

²⁷⁷ U.S. Code of Federal Regulations at CFR 430.32(c)(3).
²⁷⁸ Typical EER for units with a SEER of 14 from the AHRI database.

²⁷⁹ <https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%206.1%20CACHP%20Final%20Specification%20and%20Partner%20Commitments%20%28Rev.%20January%20%202022%29.pdf>

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Annual Energy Savings Algorithm

SEER, EER, and HSPF should be replaced with SEER2, EER2, and HSPF2 ratings in the below equations where appropriate.

If displacing/replacing electric heat:

$$\begin{aligned}\Delta kWh_{\text{total}} &= \Delta kWh_{\text{cool}} + \Delta kWh_{\text{heat}} \\ \Delta kWh_{\text{cool}} &= \text{CoolingLoadDHP} \times (1/\text{SEER}_{\text{base}} \times (1 + \Delta \text{DL}_{\text{impr}} \times \text{DL}_{\text{cool}}) \\ &\quad - 1/\text{SEER}_{\text{ee}}) \\ \Delta kWh_{\text{heat}} &= \text{HeatLoadElectricDHP} \times (3.412/\text{HSPF}_{\text{base}} \times (1 + \Delta \text{DL}_{\text{impr}} \times \text{DL}_{\text{heat}}) \\ &\quad - 3.412/\text{HSPF}_{\text{ee}})\end{aligned}$$

If displacing/replacing gas heat:

$$\begin{aligned}\Delta kWh_{\text{total}} &= \Delta kWh_{\text{cool}} - \text{Total\_kWh}_{\text{heat}} \\ \Delta kWh_{\text{cool}} &= \text{CoolingLoadDHP} \times (1/\text{SEER}_{\text{base}} \times (1 + \Delta \text{DL}_{\text{impr}} \times \text{DL}_{\text{cool}}) \\ &\quad - 1/\text{SEER}_{\text{ee}}) \\ \text{Total\_kWh}_{\text{heat}} &= (\text{HeatLoadGasDHP} \times 293.1 \times 3.412 / \text{HSPF}_{\text{ee}})\end{aligned}$$

Where:

CoolingLoadDHP

= Cooling load (kWh) that the DHP will now provide
= Actual

SEERbase

= Efficiency in SEER of existing Air Conditioner or baseline
ductless heat pump (kBtu cooling/ kWh consumed)

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Early Replacement = Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11²⁸⁰ for Central AC or 10.7 for Room AC²⁸¹. If no cooling exists, assume 154.0.

Time of Sale / New Construction = 154.0 SEER or 14.3 SEER²⁸²

SEER_{ee} = Efficiency in SEER of efficient ductless heat pump
= Actual (kBtu cooling/ kWh consumed)

HeatLoadElectricDHP
= Heating load (kWh) that the DHP will now provide
= Actual²⁸³

DL_{cool} = 1 if duct leakage applies based on baseline cooling equipment (0 otherwise)

DL_{heat} = 1 if duct leakage applies based on baseline heating equipment (0 otherwise)

ΔDL_{impr} = Duct loss improvement factor, 0.15
3.412 = Converts 1/HSPF to 1/COP

²⁸⁰ Based on Itron and Cadmus unpublished analysis of standard efficiency units by age of unit from Energy Information Administration, Residential Energy Consumption Survey, 2015, AHRI historical shipments data (<http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx>), and Energy Star historical shipments data (https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?52f9-67a), and mortality curve assumptions drawn from Cory Welch, Estimating the Useful Life of Residential Appliances, ACEEE Summer Study 2010 paper (<http://aceee.org/files/proceedings/2010/data/papers/1977.pdf>). If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

²⁸¹ Estimated by converting the minimum standard for Room A/Cs before 2005 (9.7) by 1.1 to adjust for SEER.

²⁸² Minimum Federal Standard

²⁸³ For example with a Manual-J calculation or similar modeling.

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<i>HSPFbase</i>	<i>= Heating Seasonal Performance Factor of existing system or baseline ductless heat pump for new construction</i>
<i>Early Replacement</i>	<i>= Use actual HSPF rating where it is possible to measure or reasonably estimate.</i>
	<i>If unknown assume 3.412²⁸⁴ for resistance heat, 7.15²⁸⁵ for ASHP.</i>
<i>Time of Sale / New Construction</i>	<i>= 8.8 HSPF or 7.5 HSPF₂₂ ²⁸⁶</i>
<i>HSPFee</i>	<i>= Heating Seasonal Performance Factor of ENERGY STAR ductless heat pump²⁸⁷</i>
	<i>= Actual</i>
<i>HeatLoadGasDHP</i>	<i>= Heating load (MMBTU) that the DHP will now provide</i>
	<i>= Actual²⁸⁸</i>
<i>293.1</i>	<i>= Converts MMBTU to kWh</i>
<i>AFUEexist</i>	<i>= Efficiency of existing furnace or boiler</i>
	<i>= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 84%²⁸⁹.</i>

²⁸⁴ Assume COP of 1.0 converted to HSPF by multiplying by 3.412.

²⁸⁵ This is estimated based on finding the average HSPF/SEER ratio from the AHRI directory data (using the least efficient models - SEER 12 and SEER 13) - 0.596, and applying to the existing ASHP SEER rating assumption of 12.

²⁸⁶ Minimum Federal Standard

²⁸⁷ HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within AHRI climate zone 4 which encompasses all of the Mid Atlantic region. There should therefore be no reason to adjust the rated HSPF for geographic/climate variances.

²⁸⁸ For example with a Manual-J calculation or similar modeling.

²⁸⁹ The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.

3.412 = Converts heat pump HSPF in to COP

See example calculations at end of characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = BTUH_{Cool} (1/EER_{base} \times (1 + \Delta DL_{impr} * DL_{cool}) - 1/EER_{ee}))/1,000 \times CF$$

Where:

- BTUH_{Cool}

= Cooling capacity in BTUs per hour (tons x 12,000BTU/hr per ton)
- = Actual
- EER_{base}

= Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump
- Early Replacement

= Use actual EER rating where it is possible to measure or reasonably estimate.
- If unknown assume 9.9²⁹⁰ for Central AC or 9.7 for Room AC²⁹¹.
- If no cooling is at the home, make 1/EER = 0 (resulting in a negative value i.e. increase in load).

Time of Sale / New Construction = 8.5²⁹²

²⁹⁰ Based on SEER of 11, using a formula to give 9.9 EER. The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER²) + (1.12 * SEER). See Wassmer, M. (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations," Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

²⁹¹ Using the assumption of existing unit EER efficiency in the Room Air Conditioner Early Replacement measure, based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

²⁹² Typical EER for DMSHP units with a SEER of 14 from the AHRI database

<i>EER_{ee}</i>	<i>= Energy Efficiency Ratio (EER) of Efficient ductless heat pump</i> <i>= Actual.</i>
<i>DL_{cool}</i>	<i>= 1 if duct leakage applies based on baseline cooling equipment (0 otherwise)</i>
<i>ΔDL_{impr}</i>	<i>= Duct loss improvement factor, 0.15</i>
<i>CF</i>	<i>= Coincidence Factor for measure. Assumptions for both Central AC and Room AC are provided below. The appropriate selection depends on whether the DHP is being used similarly to a central AC (thermostatically controlled) or a room AC (controlled with need). If unknown assume Room AC.</i>
<i>CF_{SSP Room AC}</i>	<i>= Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)</i> <i>= 0.31²⁹³</i>
<i>CF_{PJM Room AC}</i>	<i>= PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather</i> <i>= 0.3²⁹⁴</i>
<i>CF_{SSP Central AC}</i>	<i>= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)</i>

²⁹³ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

²⁹⁴ Consistent with coincidence factors found in:
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).

$$CF_{PJM\ Central\ AC}$$

$$= 0.69^{295}$$
$$= PJM\ Summer\ Peak\ Coincidence\ Factor\ for\ Central\ A/C$$
$$(June\ to\ August\ weekdays\ between\ 2\ pm\ and\ 6\ pm)\ valued$$
$$at\ peak\ weather$$
$$= 0.66^{296}$$

See example calculations at end of characterization.

Annual Fossil Fuel Savings Algorithm

If the existing heating system is gas fired, the savings from the measure represent the displaced gas heating consumption, and the DHP represents added electric load.

$$\Delta MMBTU$$

$$= HeatLoadGasReplaced / AFUE_{exist} * (1 + \Delta DL_{impr} * DL_{heat})$$

Where:

$$HeatLoadGasReplaced$$
$$= Heating\ load\ (MMBTU)\ that\ the\ DHP\ will\ now\ provide\ in$$
$$place\ of\ gas\ unit$$
$$= Actual^{297}$$

$$AFUE_{exist}$$

$$= Efficiency\ of\ existing\ heating\ system$$

²⁹⁵ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

²⁹⁶ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

²⁹⁷ For example with a Manual-J calculation or similar modeling.

DL_{heat} = Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 80%²⁹⁸ for early retirement, or 80% for replace on burnouts²⁹⁹.
= 1 if duct leakage applies based on baseline heating equipment (0 otherwise)

ΔDL_{impr} = Duct loss improvement factor = 0.15

See example calculations at end of characterization.

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental costs per ton for this measure are provided below:³⁰⁰

Unit Size (tons)	Time of Sale	Early Replacement
1	\$267	\$915
1.5	\$400	\$1,252
2	\$533	\$1,588

²⁹⁸ The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.

²⁹⁹ This has been estimated assuming that the average efficiency of existing heating systems is likely to include newer more efficient systems.

³⁰⁰ Itron, Mid-Atlantic TRM Version 7.0 Incremental Costs Update, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, 2010 - 2012 W0017 Ex Ante Measure Cost Study, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

2.5	\$667	\$1,925
3	\$800	\$ 2,262

Measure Life

The measure life is assumed to be 18 years³⁰¹. If an early replacement measure results in the removal of existing operating heating or cooling equipment, it is assumed that it would have needed replacing in 6 years.

Operation and Maintenance Impacts

n/a

Illustrative examples – do not use as default assumption

Early Replacement:

A 1.5 ton, 20 SEER, 14 EER, 12 HSPF, DHP replaces 5000 kWh of existing electric resistance heat load in a home without existing cooling in Baltimore, MD. DHP is estimated to provide 2,000kWh of cooling load.

$$\begin{aligned}
 \Delta kWH &= (\text{CoolingLoadDHP} \times (1/\text{SEERbase} - 1/\text{SEERee})) + \\
 &\quad (\text{HeatLoadElectricDRP} \times (3.412/\text{HSPFbase} - 3.412/\text{HSPFee})) \\
 &= (2000 \times (0 - 1/20)) + (5000 \times (3.412/3.412 - 3.412/12)) \\
 &= 3,478 \text{ kWh} \\
 \Delta kW_{SSP} &= \text{BTUH}_{\text{Cool}} \times (1/\text{EERbase} - 1/\text{EERee}) / 1,000 \times \text{CF} \\
 &= (18,000 \times (0 - 1/14)) / 1000 \times 0.31 \\
 &= - 0.40 \text{ kW}
 \end{aligned}$$

³⁰¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<https://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures>.

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A 2.5 ton, 18 SEER, 13.5 EER, 11 HSPF, DHP displaces all of the existing gas heat (78% AFUE) in a home with central cooling in Baltimore, MD. The heating load is estimated as 40 MMBTU and cooling load of 4000 kWh.

$$\begin{aligned}\Delta \text{kWh} &= (\text{CoolingLoadDHP} \times (1/\text{SEERbase} - 1/\text{SEERee})) - \\ &\quad (\text{HeatLoadGasDHP} \times 293.1 \times 0.85 \times (3.412/\text{HSPFee})) \\ &= (4000 \times (1/11 - 1/18)) - (40 \times 293.3 \times 0.85 \times (3.412/11)) \\ &= -2,952 \text{ kWh (i.e. this results in an increase in electric consumption)} \\ \Delta \text{kW}_{SSP} &= (\text{BTUH}_{\text{Cool}} \times (1/\text{EERbase} - 1/\text{EERee})) / 1,000 \times \text{CF} \\ &= (30,000 \times (1/9.96 - 1/13.5)) / 1000 \times 0.31 \\ &= 0.24 \text{ kW (in the summer you see demand savings)} \\ \Delta \text{MMBTU} &= \text{HeatLoadGasReplaced} / \text{AFUE}_{\text{exist}} \\ &= 40 / 0.80 \\ &= 50 \text{ MMBTU}\end{aligned}$$

Time of Sale / New Construction

Two 1.5 ton, 18 SEER, 13.5 EER, 11 HSPF, DHPs are installed in a new home in Baltimore, MD. The estimated heat load is 12,000kWh and the cooling load is 6,000kWh

$$\begin{aligned}\Delta \text{kWh} &= (\text{CoolingLoadDHP} \times (1/\text{SEERbase} - 1/\text{SEERee})) + \\ &\quad (\text{HeatLoadElectricDHP} \times (3.412/\text{HSPFbase} - 3.412/\text{HSPFee})) \\ &= (6000 \times (1/14 - 1/18)) + (12,000 \times (3.412/7.7 - 3.412/11)) \\ &= 1,634 \text{ kWh} \\ \Delta \text{kW}_{SSP} &= (\text{BTUH}_{\text{Cool}} \times (1/\text{EERbase} - 1/\text{EERee})) / 1,000 \times \text{CF} \\ &= (36,000 \times (1/11.8 - 1/13.5)) / 1000 \times 0.31 \\ &= 0.12 \text{ kW}\end{aligned}$$

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HE Gas Boiler

Unique Measure Code: RS_HV_TOS_GASBLR_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure characterization provides savings for the purchase and installation of a new residential sized ENERGY STAR-qualified high efficiency gas-fired boiler for residential space heating, instead of a new baseline gas boiler. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Attempt should be made to account for this interaction where the measures occur in the same home within the same program period.

Definition of Baseline Condition

The baseline condition is a boiler that meets the minimum Federal baseline AFUE for boilers. For boilers manufactured after January 15, 2021, the Federal baseline is 84% AFUE.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified boiler with an AFUE rating ≥ 90%.

Annual Energy Savings Algorithm

n/a

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Summer Coincident Peak kW Savings Algorithm
n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta\text{MMBTU} = (\text{EFLHeat} * \text{BTUH} * ((\text{AFUE}_{\text{new}}/\text{AFUE}_{\text{base}}) - 1)) / 1,000,000$$

Where:

EFLHeat = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ³⁰²
Baltimore, MD	620 ³⁰³
Washington, DC	528 ³⁰⁴

BTUH = Input Capacity of Boiler
= Actual

AFUEbase = Efficiency in AFUE of baseline boiler

³⁰² Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

³⁰³ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

³⁰⁴ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

AFUE_{ee} = 84%
= Efficiency in AFUE of efficient boiler
= Actual

Illustrative example – do not use as default assumption
The purchase and installation of a 100,000 BTU_h input capacity, 90% AFUE boiler in Maryland:

$$\Delta\text{MMBTU} = (620 * 100,000 * ((0.9/0.82) - 1)) / 1,000,000$$
$$= 6.0 \text{ MMBTU}$$

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental costs for this measure are provided below:³⁰⁵

Efficiency of Boiler (AFUE)	Incremental Cost
90%	\$469
92%	\$513
95%	\$643
98%	\$789

³⁰⁵ Costs were derived the Residential Furnace Technical support document, 2016 and adjusted for inflation to represent 2017 dollars
<https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217>

Measure Life

The measure life is assumed to be 18 years³⁰⁶.

Operation and Maintenance Impacts

n/a

³⁰⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Condensing Furnace (gas)

Unique Measure Code: RS_HV_TOS_GASFUR_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure characterization provides savings for the purchase and installation of a new residential sized ENERGY STAR-qualified high efficiency gas-fired condensing furnace for residential space heating, instead of a new baseline gas furnace. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Attempt should be made to account for this interaction where the measures occur in the same home within the same program period.

Definition of Baseline Condition

The baseline condition is a non-condensing gas furnace with an AFUE of 80% or 81% if weatherized³⁰⁷.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified gas-fired condensing furnace with an AFUE rating $\geq 90\%$.

³⁰⁷ Current federal minimum. See <http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0102-0008>.

Annual Energy Savings Algorithm

n/a. Note, if the furnace has an ECM fan, electric savings should be claimed as characterized in the “Central Furnace Efficient Fan Motor” section of the TRM.

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$\Delta\text{MMBTU} = (\text{EFLHheat} * \text{BTUH} * ((\text{AFUEee}/\text{AFUEbase}) - 1) / 1,000,000$

Where:

EFLHheat = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ³⁰⁸
Baltimore, MD	620 ³⁰⁹
Washington, DC	528 ³¹⁰

BTUH = Input Capacity of Furnace
= Actual

³⁰⁸ Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

³⁰⁹ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; “Evaluation of the High efficiency heating and cooling program, technical report”, June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

³¹⁰ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

AFUEbase

= Efficiency in AFUE of baseline Furnace

= 0.80

AFUEee

= Efficiency in AFUE of efficient Furnace

= Actual

Illustrative example – do not use as default assumption
The purchase and installation of a 100,000 BTUh, 92% AFUE furnace in Maryland:

ΔMMBTU

= (620 * 100,000 * ((0.92/0.8) – 1) /1,000,000

= 9.3 MMBTU

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided below.³¹¹

Efficiency of Furnace (AFUE)	Incremental Cost

³¹¹ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Adapted from Department of Energy, Residential Furnaces and Boilers Final Rule Technical Support Document, 2016, Table 8-2-16. <https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217>. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

90%	\$392
92%	\$429
95%	\$537
98%	\$659

Measure Life

The measure life is assumed to be 18 years³¹².

Operation and Maintenance Impacts

n/a

³¹² Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Smart Thermostat

Unique Measure Code: RS_HV_TOS_SMTHRM_0518, RS_HV_RF_SMTHRM_0518

Effective Date: May 2018

End Date: TBD

Measure Description

The Smart Thermostat measure involves the replacement of a manually operated or conventional programmable thermostat with a “smart” (advanced, wi-fi, or connected) thermostat as defined below. This measure applies to all residential applications and may be a time of sale or retrofit measure.

Definition of Baseline Condition

This is defined as a retrofit measure. The baseline equipment is an assumed (defaulted) mix of manual and programmable thermostats.

Definition of Efficient Condition

The efficient condition is a “smart” thermostat that has earned ENERGY STAR certification³¹³ and/or has the following product requirements³¹⁴:

1. Automatic scheduling
2. Occupancy sensing (set “on” as a default)

³¹³ ENERGY STAR’s qualified products list for smart thermostats:

<https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Smart-Thermostats/7p2p-wkbf>

³¹⁴ ENERGY STAR Smart Thermostat Specification, from which most requirements based:

https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0_0.pdf

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3. For homes with a heat pump, smart thermostats must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.
4. Ability to adjust settings remotely via a smart phone or online the absence of connectivity to the connected thermostat (CT) service provider, retain the ability for residents to locally:
 - a. view the room temperature,
 - b. view and adjust the set temperature, and
 - c. switch between off, heating and cooling.
5. Have a static temperature accuracy $\leq \pm 2.0$ °F
6. Have network standby average power consumption of ≤ 3.0 W average (Includes all equipment necessary to establish connectivity to the CT service provider's cloud, except those that can reasonably be expected to be present in the home, such as Wi-Fi routers and smart phones.)
7. Enter network standby after ≤ 5.0 minutes from user interaction (on device, remote or occupancy detection)
8. The following capabilities may be enabled through the CT device, CT service or any combination of the two. The CT product shall maintain these capabilities through subsequent firmware and software changes.
 - a. Ability for consumers to set and modify a schedule.
 - b. Provision of feedback to occupants about the energy impact of their choice of settings.
 - c. Ability for consumers to access information relevant to their HVAC energy consumption, e.g. HVAC run time.

Annual Energy Savings Algorithm

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As smart thermostats are control technologies, when possible, heating and cooling savings should be calculated based on data from installed thermostats.³¹⁵ Otherwise, cooling savings should only be claimed for homes with central air conditioning. Heating savings may be claimed for homes with electric resistance, heat pump, or non-electric heating. Where there is more than one smart thermostat installed to control a single fossil heating system, a per-thermostat adjustment factor is applied to savings calculations.

When heating and/or cooling consumption is known, use the following algorithms:

$$\begin{aligned}\Delta \text{kWh} &= \Delta \text{kWh}_{\text{heating}} + \Delta \text{kWh}_{\text{cooling}} \\ \Delta \text{kWh}_{\text{heating}} &= \text{Elec\_Heating\_Saving\_}\% \times \text{Elec\_Heating\_kWh} \\ \Delta \text{kWh}_{\text{cool}} &= \text{Cooling\_Saving\_}\% \times \text{Cooling\_kWh} \\ \Delta \text{MMBTU} &= \text{Fuel\_Heating\_Saving\_}\% \times \text{Fuel\_Heating\_MMBTU} \times \text{QUANT} \times \text{QUANTafh}\end{aligned}$$

Where:

$$\begin{aligned}\text{Elec\_Heating\_Saving\_}\% &= 6\% \\ \text{Cooling\_Saving\_}\% &= 7\% \\ \text{Fuel\_Heating\_Saving\_}\% &= 6\%^{316} \\ \text{Elec\_Heating\_kWh} &= \text{actual seasonal electric heat kWh consumption} \\ \text{Cooling\_kWh} &= \text{actual seasonal cooling kWh consumption}\end{aligned}$$

³¹⁵ NEEP has developed a Guidance Document detailing methodology to claim savings from smart thermostats, available here: <http://www.neep.org/claiming-savings-smart-thermostats-guidance-document>. This guidance uses the metric developed for the ENERGY STAR certification to develop geographically and temporally specific savings averages for program claims. These calculated savings numbers are expected to be more accurate and potentially yield higher level of savings than the estimates provided in the TRM.

³¹⁶ Smart thermostat deemed savings percentages drawn from 2017 literature survey performed by Joe Loper of Itron, see Smart_Thermostat_Literature_Summary_WORKING022417.xls

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Fuel_Heating_MMBTU = actual seasonal fossil heating MMBTU consumption
 QUANT = number of smart thermostats connected to a single fossil heating system
 QUANTafh = adjustment factor for installed measure quantity with heating system
 = 1.0 (if QUANT = 1);
 = .727³¹⁷ (if QUANT >1)

Where actual heating or cooling energy consumption is not known, use the following algorithms:

Cooling Savings:

$$\Delta kWh = \frac{CCAP}{SEER} \times EFLHc \times \text{Cooling\_Saving\_}\%$$

Electric Heat Savings:

$$\Delta kWh = \frac{HCAPElec}{HSPF} \times EFLHh \times \text{Elec\_Heating\_Saving\_}\%$$

Fossil heat Savings:

³¹⁷ Cadmus Wi-Fi program evaluation for MA reported gas heat savings per thermostat of 11% for 1, and 8% for 2. Adjustment factor is based on these findings. 8%/11% = .727 adjustment factor if >1 wi-fi thermostat is connected to the same heating system.
http://ma-eeac.org/wordpress/wp-content/uploads/Wi-Fi-Programmable-Controllable-Thermostat-Pilot-Program-Evaluation_Part-of-the-Massachusetts-2011-Residential-Retrofit-Low-Income-Program-Area-Study.pdf

$$\Delta\text{MMBTU} = \frac{\text{HCAP}_{\text{fuel}}}{\text{AFUE}} \times \text{EFLH} \times \text{Fuel\_Heating\_Saving}_{\%} \times \text{QUANT} \times \text{QUANT}_{\text{afh}}$$

Where:

CCAP	= Cooling capacity of existing AC unit, in kBTU/hr.
HCAP _{elec}	= Heating capacity of existing electric heat unit, in kBTU/hr.
HCAP _{fuel}	= Heating capacity of existing fossil heat unit, in MMBTU/hr.
SEER	= SEER of controlled unit. If unknown use current energy code requirements for mechanical cooling efficiency.
HSPF	= HSPF of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency. Electric strip heat = 1.
AFUE	= AFUE of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency.
EFLH _{cool}	= Full load hours for cooling equipment. See tables below.
EFLH _{heat}	= Full load hours for heating equipment. See tables below
QUANT	= number of smart thermostats connected to a single fossil heating system
QUANT _{afh}	= adjustment factor for installed measure quantity with heating system = 1.0 (if QUANT = 1); = .727 ³¹⁸ (if QUANT >1)

³¹⁸ Cadmus Wi-Fi program evaluation for MA reported gas heat savings per thermostat of 11% for 1, and 8% for 2. Adjustment factor is based on these findings. 8%/11% = .727 adj factor if >1 wi-fi thermostat is connected to the same heating or cooling system.

EFLHheat for Air Source Heat Pump

Location	EFLHheat
Wilmington, DE	935 ³¹⁹
Baltimore, MD	866 ³²⁰
Washington, DC	822

EFLHheat Gas Furnace and Boiler; Ground Source Heat Pump

Location	EFLH
Wilmington, DE	848 ³²¹

http://ma-eeac.org/wordpress/wp-content/uploads/Wi-Fi-Programmable-Controllable-Thermostat-Pilot-Program-Evaluation_Part-of-the-Massachusetts-2011-Residential-Retrofit-Low-Income-Program-Area-Study.pdf

³¹⁹ Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator.

(http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)
³²⁰ Based on average of 5 utilities, two program years, in Maryland from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program." April 4, 2014, table 30, page 48.

³²¹ Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

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<i>Baltimore, MD</i>	<i>620³²²</i>
<i>Washington, DC</i>	<i>528³²³</i>

EFLHcool for Air Source Heat Pump, split system

<i>Location</i>	<i>EHLHcool</i>
<i>Wilmington, DE</i>	<i>719³²⁴</i>
<i>Baltimore, MD</i>	<i>744³²⁵</i>
<i>Washington, DC</i>	<i>935</i>

EFLHcool for Central AC, ducted split system; GSHP

<i>Location</i>	<i>Run Hours</i>

³²² Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

³²³ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: $620 \times 2957 / 3457 = 528$ hours.

³²⁴ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (744 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

³²⁵ Based on average of 5 utilities in Maryland from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31 2013) Residential HVAC Program." April 4, 2014, Table 30, page 48.

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Wilmington, DE	524 ³²⁶
Baltimore, MD	542 ³²⁷
Washington, DC	681

Elec_Heating_kWh, Cooling_kWh, and Fuel_Heating_MMBTU should be based on local average consumption for participants targeted by the program. If unknown, use the following table. Note that the adjustment factor of .727 should be applied to savings if more than one smart thermostat is connected to the same fossil heating system.

Baseline Energy Consumption						
State	HVAC Replacement?	Unknown	HVAC Unit Not Replaced		HVAC Unit Replaced	
	HVAC Types	Mixed	CAC w/ Central Heating	ASHP	CAC w/ Central Heating	ASHP
MD	Cooling (kWh)	2,105	1,774	2,435	1,148	1,576
	Heating (kWh)	2,296	NA	4,585	NA	3,282
	Heating (MMBTU)	30.9	62.0	NA	52.2	NA
DE	Cooling (kWh)	2,035	1,715	2,353	1,110	1,523
	Heating (kWh)	2,479	NA	4,950	NA	3,543
	Heating (MMBTU)	42.3	84.8	NA	71.4	NA

³²⁶ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

³²⁷ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

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DC	Cooling (kWh)	2,645	2,229	3,060	1,442	1,980
	Heating (kWh)	2,179	NA	4,352	NA	3,115
	Heating (MMBTU)	26.4	52.8	NA	44.5	NA

Demand Savings

The smart thermostat measure as defined here (i.e., without a corresponding demand reduction program) is assumed to have no demand savings. Smart thermostats with a demand response program added on top may generate significant demand savings, but those are not quantified as part of this measure.

Annual Water Savings Algorithm

n/a

Incremental Cost

If the costs are not known, then the incremental cost for a time of sale replacement is assumed to be \$154³²⁸ and the incremental cost for a retrofit replacement is assumed to be \$208.³²⁹ If thermostats are professionally installed, \$50 for labor should be added to the assumed incremental cost.

³²⁸ From NEEP's 2016 Incremental Cost Study: <http://www.neep.org/incremental-cost-emerging-technology-0>, table 3-13 found range of incremental costs to be \$80-195 (with baseline as \$54 and using Nest/Ecobee at \$249). NEEP's more recent list of home energy management systems products (<http://neep.org/initiatives/high-efficiency-products/home-energy-management-systems>) shows a straight average of 68 products at \$210 for the cost of the smart thermostat, bringing the incremental cost assuming \$54 for baseline down to \$154.

³²⁹ From NEEP's 2016 Incremental Cost Study: <http://www.neep.org/incremental-cost-emerging-technology-0>, table 3-13 found range of incremental costs to be \$80-195 (with baseline as \$54 and using Nest/Ecobee at \$249). NEEP's more recent list of home energy management systems products (<http://neep.org/initiatives/high-efficiency-products/home-energy-management-systems>) shows a straight average of 68 products at \$210 for the cost of the smart thermostat, bringing the incremental cost assuming \$54 for baseline down to \$154.

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Measure Life

The measure life is assumed to be 7.5 years.³³⁰

Operation and Maintenance Impacts

n/a

³³⁰ Based on professional judgment of TRM technical team and stakeholder consensus. EULs observed include: 11 years in AR TRM and 10 years in IL TRM, both of which are based on programmable thermostat EULs. CA workpapers conclude 3-year EUL using persistence modeling. RTF concludes a 5-year EUL based on CA workpapers and concerns that there is little basis for assuming long-time persistence of savings, considering past challenges with manual overrides and “know-how” needed to use wifi-connected devices, including communicating hardware and software downloading. For discussion, see Northwest Regional Technical Forum January 2017. <https://rtf.nwcouncil.org/measure/connected-thermostats> RTF_ResConnectedTstats_v1.1

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Room Air Conditioner, Time of Sale

Unique Measure Code(s): RS HV TOS RA/CES 0414, RS HV TOS RA/CT2 0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a room air conditioning unit that meets the ENERGY STAR minimum qualifying efficiency specifications presented below. Note that if the AC unit is connected to a network in a way to enable it to respond to energy related commands, it gets a 5% extra CEER allowance. In these instances, the efficient CEER would be 0.95 multiplied by the appropriate CEER from the table below.

Commented [A2]: Note - the federal minimums for this measure increase starting 1/1/2024 and will need to be updated

Product Type and Class (BTU/hour)		Federal Standard with louvered sides (CEER)	Federal Standard without louvered sides (CEER)	ENERGY STAR with louvered sides (CEER)	ENERGY STAR without louvered sides (CEER)
Without Reverse Cycle	< 8,000	11.0	10.0	12.1	11.0
	8,000 to 10,999	10.9	9.6	12.0	10.6
	11,000 to 13,999	10.9	9.5	12.0	10.5
	14,000 to 19,999	10.7	9.3	11.8	10.2
	20,000 to 24,999	9.4	9.4	10.3	10.3
	25,000 to 27,999	9.0	9.4	10.3	10.3
	>=28,000	9.0	9.4	9.9	10.3
	<14,000	NA	9.3	NA	10.2

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With Reverse Cycle	<u>>= 14,000</u>	<u>NA</u>	<u>8.7</u>	<u>NA</u>	<u>9.6</u>
	<u><20,000</u>	<u>9.8</u>	<u>NA</u>	<u>10.8</u>	<u>NA</u>
	<u>>=20,000</u>	<u>9.3</u>	<u>NA</u>	<u>10.2</u>	<u>NA</u>
<u>Casement only</u>		<u>9.5</u>		<u>10.5</u>	
<u>Casement-Slider</u>		<u>10.4</u>		<u>11.4</u>	

Definition of Baseline Condition
The baseline condition is a window AC unit that meets the minimum federal efficiency standards presented above.

Definition of Efficient Condition
The efficient condition is a window AC unit that meets the ENERGY STAR v4.2³³¹.

Annual Energy Savings Algorithm
$$\Delta kWh = (Hours * BTU/hour * (1/CEERbase - 1/CEERee))/1000$$

Where:
Hours = Run hours of Window AC unit

³³¹
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.2%20Room%20Air%20Conditioners%20Specification_0.pdf

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Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \text{BTU/hour} * (1/\text{CEER}_{\text{base}} - 1/\text{CEER}_{\text{ee}}) / 1000 * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.31³³⁶

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.3³³⁷

Using deemed values above:

$$\begin{aligned} \Delta kW_{\text{SSP}} &= (8500 * (1/10.9 - 1/12)) / 1000 * 0.31 \\ &= 0.022 \text{ kW} \end{aligned}$$

$$\Delta kW_{\text{PJM}}$$

³³⁶ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

³³⁷ Consistent with coincidence factors found in:

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).

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$$\begin{aligned} &= (8500 * (1/10.9 - 1/12)) / 1000 * 0.30 \\ &= 0.021 \text{ kW} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost³³⁸

The lifecycle NPV incremental cost for this time of sale measure is \$20.

Measure Life

The measure life is assumed to be 12 years.³³⁹

Operation and Maintenance Impacts

n/a

³³⁸ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update, 2017*. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

³³⁹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. <http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.pdf>

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Room Air Conditioner, Early Replacement

Unique Measure Code: RS_HV_EREP_RA/CES_0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure describes the early removal of an existing inefficient Room Air Conditioner unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR [V4.2³⁴⁰](#) qualifying unit. This measure is suitable for a Low Income or a Home Performance program.

Savings are calculated between the existing unit and the new efficient unit consumption during the assumed remaining life of the existing unit, and between a hypothetical new baseline unit and the efficient unit consumption for the remainder of the measure life.

Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard (i.e. with an efficiency rating of 10.9 CEER³⁴¹).

Definition of Efficient Condition

³⁴⁰ https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.2%20Room%20Air%20Conditioners%20Specification_0.pdf

³⁴¹ Minimum Federal Standard for most common Room AC type - 8000-14,999 capacity range with louvered sides.

Commented [A3]: Efficient equipment will need to be updated for 1/1/2024 min federal efficiencies

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The efficient condition is a new replacement room air conditioning unit meeting the ENERGY STAR efficiency standard (i.e. with a CEER efficiency rating greater than or equal to 12.0³⁴²).

Annual Energy Savings Algorithm

Savings for remaining life of existing unit (1st 3 years)

$$\Delta kWh = (Hours * BTUH * (1/EE_{Rexist} - 1/CEER_{ee}))/1,000$$

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (Hours * BTUH * (1/CEER_{base} - 1/CEER_{ee}))/1,000$$

Where:

Hours = Run hours of Window AC unit
= 325 ³⁴³

BTUh = Capacity of replaced unit
= Actual or 8,500 if unknown ³⁴⁴

EE_{Rexist} = Efficiency of existing unit in BTUs per Watt-hour

³⁴² Minimum qualifying for ENERGY STAR most common Room AC type - 8000-14,999 capacity range with louvered sides.

³⁴³ VEIC calculated the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) at 31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

³⁴⁴ Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

$$\begin{aligned} &= 9.8^{345} \\ CEER_{base} &= \text{Efficiency of baseline unit in BTUs per Watt-hour} \\ &= 10.9^{346} \\ CEER_{ee} &= \text{Efficiency of ENERGY STAR unit in BTUs per Watt-hour} \\ &= \text{Actual or CEER 12 if unknown} \end{aligned}$$

Illustrative example – do not use as default assumption

Replacing existing 8,500 BTUh Room AC unit with a new ENERGY STAR unit with CEER rating of 12:

Savings for remaining life of existing unit (1st 3 years)

$$\Delta kWh = (325 * 8,500 * (1/9.8 - 1/12)) / 1,000$$

$$= 52 \text{ kWh}$$

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (325 * 8,500 * (1/10.9 - 1/12)) / 1,000$$

$$= 23 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

Savings for remaining life of existing unit (1st 3 years)

$$\Delta kW = ((BTUH * (1/EER_{exist} - 1/CEER_{ee}))/1000) * CF$$

³⁴⁵ Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.

³⁴⁶ Minimum Federal Standard for capacity range.

Savings for remaining measure life (next 9 years)

$$\Delta kW = ((BTUH * (1/CEER_{base} - 1/CEER_{ee}))/1000) * CF$$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)
= 0.31³⁴⁷

CF_{PJM} = PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.3³⁴⁸

Illustrative example – do not use as default assumption

Replacing existing 8,500 BTU/h Room AC unit with a new ENERGY STAR unit with CEER rating of 12.0.

Savings for remaining life of existing unit (1st 3 years)

$$\begin{aligned}\Delta kW_{SSP} &= ((8,500 * (1/9.8 - 1/12)) / 1,000) * 0.31 \\ &= 0.0493 \text{ kW}\end{aligned}$$

³⁴⁷ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

³⁴⁸ Consistent with coincidence factors found in:

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).

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Savings for remaining measure life (next 9 years)

$$\Delta kW_{SSP} = ((8,500 * (1/10.9 - 1/12)) / 1,000) * 0.31$$
$$= 0.0222 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental cost for this early replacement measure is provided below.³⁴⁹

Product Type and Class (BTU/hour) Specified by Mid A TRM		With Louvered Sides	Without Louvered Sides
Without Reverse Cycle	< 8,000	\$244	\$205
	8,000 to 10,999	\$361	\$311
	11,000 to 13,999	\$451	\$398
	14,000 to 19,999	\$579	\$523
	20,000 to 24,999	\$692	\$692

³⁴⁹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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	25,000 to 27,999	\$809	\$812
	>=28,000	\$896	\$911
With Reverse Cycle	<14,000	NA	\$313
	>= 14,000	NA	\$592
	<20,000	\$333	NA
	>=20,000	\$764	NA

Measure Life

The measure life is assumed to be 12 years³⁵⁰. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced³⁵¹.

Operation and Maintenance Impacts

The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have occurred in 3 years, had the existing unit not been replaced) should be calculated as:

$$\text{NPV}_{\text{deferred replacement cost}} = (\text{Actual Cost of ENERGY STAR unit} - \$240^{352}) * 86\%^{353}.$$

Note that this is a lifecycle cost savings (i.e. a negative cost).

³⁵⁰ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

³⁵¹ Based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

³⁵² Itron Incremental Cost Review 2017

³⁵³ With a discount rate of 5%, the net present value of replacement in year 4 would be $0.95^3 = 0.86$.

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Room Air Conditioner, Early Retirement / Recycling

Unique Measure Code: RS_HV_ERET_RA/C_0414
Effective Date: June 2014
End Date: TBD

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Measure Description

This measure describes the savings resulting from implementing a drop off service taking existing working inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that a percentage of these units will ultimately be replaced with a baseline standard efficiency unit (note that if it is actually replaced by a new ENERGY STAR qualifying unit, the savings increment between baseline and ENERGY STAR should be captured under the ENERGY STAR Room AC Time of Sale measure).

Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit.

Definition of Efficient Condition

Not applicable. This measure relates to the retiring of an existing inefficient unit. A percentage of units however are assumed to be replaced with a baseline new unit and the savings are therefore reduced to account for these replacement units.

Annual Energy Savings Algorithm

$$\Delta kWh = ((Hours * BTUH * (1/EER_{exist}))/1,000) - (\%replaced * ((Hours * BTUH * (1/EER_{newbase}))/1,000))$$

Where:

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<i>Hours</i>	<i>= Run hours of Window AC unit</i> <i>= 325³⁵⁴</i>
<i>BTU/hour</i>	<i>= Capacity of replaced unit</i> <i>= Actual or 8,500 if unknown³⁵⁵</i>
<i>EERexist</i>	<i>= Efficiency of existing unit in BTUs per Watt-hour</i> <i>= Actual or 9.8 if unknown³⁵⁶</i>
<i>%replaced</i>	<i>= Percentage of units dropped off that are replaced in the home</i> <i>= 76%³⁵⁷</i>
<i>CEERnewbase</i>	<i>= Efficiency of new baseline unit in BTUs per Watt-hour</i> <i>= 10.9³⁵⁸</i>

³⁵⁴ VEIC calculated the average ratio of FLH for Room AC (provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008) to FLH for Central Cooling (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls) at 31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

³⁵⁵ Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

³⁵⁶ Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.

³⁵⁷ 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% were replaced with ENERGY STAR units and 13% with non-ENERGY STAR. However this formula assumes all are non-ENERGY STAR since the increment of savings between baseline units and ENERGY STAR would be recorded by the Time of Sale measure when the new unit is purchased.

³⁵⁸ Minimum Federal Standard for most common Room AC type - 8000-14,999 capacity range with louvered sides. Note that we assume the replacement is only at federal standard efficiency for the reason explained above. Current federal standards use CEER while previous federal standards used EER for efficiency levels.

Illustrative example – do not use as default assumption
The turn in of an 8,500 BTUh, 7.7 EER unit:

$$\begin{aligned}\Delta \text{kWh} &= ((325 * 8,500 * (1/9.8))/1,000) - \\ &\quad (0.76 * ((325 * 8,500 * (1/10.9))/1,000)) \\ &= 89 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = [(\text{BTUH} * (1/\text{EER}_{\text{exist}})/1,000) - (\% \text{replaced} * \text{BTUH} * (1/\text{CEER}_{\text{newbase}})/1,000)] * \text{CF}$$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)

= 0.31³⁵⁹

CF_{PJM} = PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather

= 0.3³⁶⁰

³⁵⁹ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

³⁶⁰ Consistent with coincidence factors found in:

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).

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Illustrative example – do not use as default assumption
The turn in of an 8500 BTUh, 9.8 EER unit:

$$\begin{aligned}\Delta kW_{SSP} &= ((8,500 * (1/9.8))/1,000) * 0.31 - \\ &\quad (0.76 * ((8,500 * (1/10.9))/1,000)) * 0.31 \\ &= 0.09 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental cost for this measure should be the actual implementation cost for recycling the existing unit, plus \$184 to account for the replacement of 76% of the units.³⁶¹

Measure Life
The measure life is assumed to be 3 years³⁶².

Operation and Maintenance Impacts

³⁶¹ The \$184 replacement cost was calculated by multiplying the percentage assumed to be replaced (76%) by the assumed cost of a standard efficiency unit of \$242 (=0.76 * \$242 = \$184). Cost is from Itron 2017 measure cost update available on NEEP website.

³⁶² 3 years of remaining useful life based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

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The net present value of the deferred replacement cost (the cost associated with the replacement of those units that would be replaced, with a standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as \$158³⁶³.

³⁶³ Determined by calculating the Net Present Value (with a 5% discount rate) of the annuity payments from years 4 to 12 of a deferred replacement of a standard efficiency unit costing multiplied by the 76%, the percentage of units being replaced (i.e. $0.76 * \$170 = \$129.2$. Baseline cost from ENERGY STAR calculator;
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)

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Boiler Pipe Insulation

Unique Measure Code: RS_HV_RF_PIPEIN_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes adding insulation to un-insulated boiler pipes in un-conditioned basements or crawlspaces.

Note, the algorithm provided to calculate savings may be used to determine an appropriate deemed savings value if the programs can provide appropriate average values for each of the variables.

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is an un-insulated boiler pipe.

Definition of Efficient Condition

The efficient condition is installing pipe wrap insulation to a length of boiler pipe.

Annual Energy Savings Algorithm

N/A

Summer Coincident Peak kW Savings Algorithm

N/A

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBTU} = (((1/R_{\text{exist}}) - (1/R_{\text{new}})) * \text{FLH}_{\text{heat}} * C_{\text{exist}} * L * \Delta T) / \eta_{\text{Boiler}} / 1,000,000$$

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Where:

- R_{exist}

= Pipe heat loss coefficient of uninsulated pipe [(hr-°F-ft²)/BTU]
= 0.5³⁶⁴
- R_{new}

= Pipe heat loss coefficient of insulated pipe [(hr-°F-ft²)/BTU]
= Actual (0.5 + R value of insulation)
- $EFLH_{heat}$

= Equivalent Full load hours of heating

Location	EFLH
Wilmington, DE	848 ³⁶⁵
Baltimore, MD	620 ³⁶⁶
Washington, DC	528 ³⁶⁷

- L

= Length of boiler pipe in unconditioned space covered by pipe wrap (ft)

³⁶⁴ Assumption based on data obtained from the 3E Plus heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association) and derived from Table 15 and Table 16 of 2009 ASHRAE Fundamentals Handbook, Chapter 23 Insulation for Mechanical Systems, page 23.17.

³⁶⁵ Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

³⁶⁶ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; “Evaluation of the High efficiency heating and cooling program, technical report”, June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

³⁶⁷ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

= Actual

C_{exist} = Circumference of bare pipe (ft) (Diameter (in) * $\pi/12$)
= Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature (°F)³⁶⁸

Pipes location	Outdoor Reset Controls	ΔT (°F)
Unconditioned basement	Boiler without reset control	110
	Boiler with reset control	70
Crawlspace	Boiler without reset control	120
	Boiler with reset control	80

η_{Boiler} = Efficiency of boiler
= 0.84³⁶⁹

Illustrative example – do not use as default assumption
Insulating 15 feet of 0.75" pipe with R-3 wrap (0.75" thickness) in a crawl space in Wilmington, DE with a boiler without reset controls:

$$\Delta \text{MMBTU} = (((1/R_{\text{exist}}) - (1/R_{\text{new}})) * \text{FLH\_heat} * C_{\text{exist}} * L * \Delta T) / \eta_{\text{Boiler}} / 1,000,000$$

³⁶⁸ Assumes 160° F water temp for a boiler without reset control, 120° F for a boiler with reset control, and 50° F air temperature for pipes in unconditioned basements 40° F for pipes in crawlspaces (Zone 4; NCDC 1881-2010 Normals, average of monthly averages Nov - Apr for zones 1-3 and Nov-March for zones 4 and 5).

³⁶⁹ Assumed efficiency of existing boilers.

$$= (((1/0.5) - (1/3.5)) * 848 * 0.196 * 15 * 120) / 0.85 / 1,000,000$$

$$= 0.63 \text{ MMBTU}$$

Annual Water Savings Algorithm

N/A

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure should be the actual unit cost plus labor cost. If unknown, the measure cost including material and installation is assumed to be \$3 per linear foot.³⁷⁰

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 15 years³⁷¹.

Operation and Maintenance Impacts

N/A

³⁷⁰ Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

³⁷¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Boiler Reset Controls

Unique Measure Code: RS_HV_RF_BLRRES_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.

Definition of Baseline Condition

Existing condensing boiler in a single family residential setting without boiler reset controls.

Definition of Efficient Condition

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer’s recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single family residence. Boiler reset controls for non-condensing boilers in single family

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residences should be implemented as a custom measure, and the cost-effectiveness should be confirmed.

Annual Energy Savings Algorithm
n/a

Summer Coincident Peak kW Savings Algorithm
n/a

Annual Fossil Fuel Savings Algorithm
$$\Delta\text{MMBTU} = (\text{Savings \%}) * (\text{EFLHheat} * \text{BTUh}) / 1,000,000$$

Where:

Savings % = Estimated percent reduction in heating load due to boiler reset controls being installed
= 5%³⁷²

EFLHheat = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ³⁷³

³⁷² Energy savings factor for residential applications taken from an article published by the Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See: <http://cleanboiler.org/learn-about/boiler-efficiency-improvement/efficiency-index/boiler-reset-control/>

³⁷³ Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

Baltimore, MD	620 ³⁷⁴
Washington, DC	528 ³⁷⁵

BTUH = Input Capacity of Boiler
= Actual

Illustrative example – do not use as default
A boiler reset control is applied to a 80,000 BTUH boiler in Baltimore, MD.

$$\Delta \text{MMBTU} = 0.05 * (620 * 80,000) / 1,000,000$$
$$= 2.48 \text{ MMBTU}$$

Annual Water Savings Algorithm
n/a

Incremental Cost
The cost of this measure is \$612³⁷⁶

Measure Life
The life of this measure is 15 years³⁷⁷

³⁷⁴ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHeat assumption.

³⁷⁵ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: 620 * 2957 / 3457 = 528 hours.

³⁷⁶ Nexant. Questar DSM Market Characterization Report. August 9, 2006.

³⁷⁷ New York State TRM v4.0, April 2016

Operation and Maintenance Impacts
n/a

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Ground Source Heat Pumps

Unique Measure Code: RS_HV_TOS_GSHPS_0518, RS_HV_NC_GSHPS_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure characterizes the installation of an ENERGY STAR qualified Ground Source Heat Pump (GSHP) either during new construction or at Time of Sale/Replacement of an existing system(s). The baseline is always assumed to be a new baseline Air Source Heat Pump. Savings are calculated due to the GSHP providing heating and cooling more efficiently than a baseline ASHP, and where a desuperheater is installed, additional Domestic Hot Water (DHW) savings occur due to displacing existing water heating.

The ENERGY STAR efficiency standards are presented below.

ENERGY STAR Requirements (Effective January 1, 2012)

Product Type	Cooling EER	Heating COP
Water-to-air		
Closed Loop	17.1	3.6
Open Loop	21.1	4.1
Water-to-Water		
Closed Loop	16.1	3.1
Open Loop	20.1	3.5
Direct Geoexchange ³⁷⁸	16	3.6

³⁷⁸ Direct GeoExchange (DGX) is defined by Energy Star as: "A geothermal heat pump model in which the refrigerant is circulated in pipes buried in the ground or submerged in water that exchanges heat with the ground, rather than using a secondary heat transfer fluid, such as water or antifreeze solution in a separate closed loop." See https://www.energystar.gov/products/heating_cooling/heat_pumps_geothermal/key_product_criteria.

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Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Comprehensive building efficiency improvements will reduce load and may lead to downsizing of space conditioning equipment. To properly account for these interactive effects, energy modeling should be performed and those results should be used for savings attribution in place of savings algorithms shown here. Effects of HVAC downsizing can be attributed to either weatherization or HVAC, but not both.

Definition of Baseline Condition

New Construction:

The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 15.4 SEER, 8.82 HSPF and 12.51-8³⁷⁹ EER. If a desuperheater is installed, the baseline for DHW savings is assumed to be a Federal Standard electric hot water heater, with Energy Factor calculated as follows³⁸⁰:

For <=55 gallons:	EF	= 0.9307 – (0.0002 x rated volume in gallons)
For >55 gallons:	EF	= 2.1171 – (0.0011 x rated volume in gallons)

If size is unknown, assume 50 gallons; 0.921 EF.

Time of Sale:

The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8 EER. If a desuperheater is

³⁷⁹ The Federal Standard does not include an EER requirement, so it is approximated with this formula: (-0.02 * SEER²) + (1.12 * SEER) Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

³⁸⁰ U.S. Code of Federal Regulations at 10 CFR 430.32(d) (2021). Assumes “medium” draw pattern.

installed, the baseline for DHW savings is assumed to be the existing home's hot water heater fuel and efficiency.

If electric DHW, and unknown efficiency – assume efficiency is equal to pre 4/2015 Federal Standard:

$$EF = 0.93 - (0.00132 \times \text{rated volume in gallons})^{381}$$

If size is unknown, assume 50 gallons; 0.864 EF

If gas water heater, and unknown efficiency – assume efficiency is equal to pre 4/2015 Federal Standard:

$$EF = (0.67 - 0.0019 \times \text{rated volume in gallons})^{382}$$

If size is unknown, assume 40 gallons; 0.594 EF

If DHW fuel is unknown, assume electric DHW provided above.

Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed above.

Annual Energy Savings Algorithm

³⁸¹ Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

³⁸² Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

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$$\Delta kWh = [Cooling\ savings] + [Heating\ savings] + [DHW\ savings]$$
$$= [(FLH_{cool} \times BTU_c \times (1/SEER_{base} - (1/EER_{PL})/1000)] +$$
$$[FLH_{heat} \times BTU_h \times (1/HSPF_{base} - (1/(COP_{PL} \times 3.412)))/1000] + [ElecDHW \times$$
$$\%DHW_{Displaced} \times (((1/EF_{ELEC}) \times GPD \times Household \times 365.25 \times \gamma_{Water} \times$$
$$(T_{OUT} - T_{IN}) \times 1.0) / 3412)]$$

Where:

FLH_{cool} = Full load cooling hours
Dependent on location as below:

Location	Run Hours
Wilmington, DE	524 ³⁸³
Baltimore, MD	542 ³⁸⁴
Washington, DC	681

BTU_c = Cooling capacity in BTUs per hour (tons x 12,000BTU/hr)
BTU_h = Heating capacity in BTUs per hour (tons x 12,000BTU/hr)
SEER_{base} = SEER Efficiency of new replacement baseline unit
= 15.4³⁸⁵

³⁸³ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)
³⁸⁴ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.
³⁸⁵ Minimum Federal Standard as of 1/1/2015;
<http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>

EER_{FL} = Full Load EER Efficiency of efficient GSHP unit³⁸⁶
= Actual installed

FLH_{heat} = Full load heating hours

Location	EFLH
Wilmington, DE	848 ³⁸⁷
Baltimore, MD	620 ³⁸⁸
Washington, DC	528 ³⁸⁹

$HSPF_{base}$ = Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)
= 8.82³⁹⁰

COP_{FL} = Full Load Coefficient of Performance of efficient unit³⁹¹
= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

³⁸⁶ As per Navigant-Cadmus 2017-2018 Deemed Savings Exception memo.

³⁸⁷ Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

³⁸⁸ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

³⁸⁹ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: $620 * 2957 / 3457 = 528$ hours.

³⁹⁰ Minimum Federal Standard as of 1/1/2015;

<http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf>

³⁹¹ As per Navigant-Cadmus 2017-2018 Deemed Savings Exception memo

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ElecDHW = 1 if existing DHW is electrically heated
 = 0 if existing DHW is not electrically heated
%DHWDIsplaced = Percentage of total DHW load that the GSHP will provide
 = Actual if known
 = If unknown and if desuperheater installed assume 44%³⁹²
 = 0% if no desuperheater installed
EF_{ELEC} = Energy Factor (efficiency) of electric water heater
 For new construction assume federal standard³⁹³:
 For ≤55 gallons: $0.9307 - (0.0002 \times \text{rated volume in gallons})$
 For >55 gallons: $2.1171 - (0.0011 \times \text{rated volume in gallons})$
 If size is unknown, assume 50 gallon; 0.921 EF.
 For Time of Sale, if electric DHW use Actual efficiency. If unknown
 – assume efficiency is equal to pre 4/2015 Federal Standard:
 $EF = 0.93 - (0.00132 \times \text{rated volume in gallons})$ ³⁹⁴
 If size is unknown, assume 50 gallon; 0.864 EF

³⁹² Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year ($2/3 \times 2/3 = 44\%$). Based on input from Doug Dougherty, Geothermal Exchange Organization.

³⁹³ U.S. Code of Federal Regulations at 10 CFR 430.32(d) (2021). Assumes “medium” draw pattern.

³⁹⁴ Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_f_r.pdf

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<i>GPD</i>	<i>= Gallons Per Day of hot water use per person</i> <i>= 45.5 gallons hot water per day per household/2.59 people per household³⁹⁵</i> <i>= 17.6</i>
<i>Household</i>	<i>= Average number of people per household</i> <i>= 2.53 ³⁹⁶</i>
<i>365.25</i>	<i>= Days per year</i>
<i>yWater</i>	<i>= Specific weight of water</i> <i>= 8.33 pounds per gallon</i>
<i>T_{OUT}</i>	<i>= Tank temperature</i> <i>= 125°F</i>
<i>T_{IN}</i>	<i>= Incoming water temperature from well or municipal system</i> <i>= 60.9 ³⁹⁷</i>
<i>1.0</i>	<i>= Heat Capacity of water (1 BTU/lb°F)</i>
<i>3412</i>	<i>= Conversion from BTU to kWh</i>

Illustrative Example – do not use as default assumption

New Construction:

³⁹⁵ Based upon email message from Maureen Hodgins, Research Manager for Water Research Foundation, on August 26, 2014.

³⁹⁶ US Energy Information Administration, Residential Energy Consumption Survey 2009; <http://www.eia.gov/consumption/residential/data/2009/xls/HC9.10%20Household%20Demographics%20in%20South%20Region.xls>

³⁹⁷ Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

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For example, a 3-ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50-gallon electric water heater in single family house in Baltimore:

$$\Delta \text{kWh} = [(\text{FLHcool} \times \text{BTUc} \times (1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}})/1000) + [(\text{FLHheat} \times \text{BTUh} \times (1/\text{HSPF}_{\text{base}} - (1/\text{COP}_{\text{PL}} \times 3.412)))/1000] + [\text{ElecDHW} \times \% \text{DHWD} \text{Displaced} \times (((1/\text{E}_{\text{ELEC EXIST}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)])]$$

$$\Delta \text{kWh} = [(542 \times 36,000 \times (1/14 - 1/19)) / 1000] + [(620 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412))) / 1000] + [1 \times 0.44 \times (((1/0.921) \times 17.6 \times 2.53 \times 365.25 \times 8.33 \times (125 - 60.9) \times 1) / 3412)]$$

$$= 367 + 1235 + 1216$$

$$= 2818 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = (\text{BTUc} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{FL}})) / 1000 \times \text{CF}$$

Where:

EER_{base} = EER Efficiency of new replacement unit

= 12.51³⁹⁸

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit³⁹⁹

= Actual

³⁹⁸ The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.

³⁹⁹ As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP.

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CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69⁴⁰⁰

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.66⁴⁰¹

Illustrative Example– do not use as default assumption

New Construction or Time of Sale:

For example, a 3-ton unit with Full Load EER rating of 19:

$$\begin{aligned}\Delta kW_{SSP} &= ((36,000 \times (1/11.8 - 1/19))/1000) \times 0.69 \\ &= 0.80 \text{ kW} \\ \Delta kW_{PJM} &= ((36,000 \times (1/11 - 1/19))/1000) \times 0.66 \\ &= 0.76 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

Savings for Time of Sale where existing hot water heater is gas fired:

$$\begin{aligned}\Delta \text{MMBTU} &= [\text{DHW Savings}] \\ &= [(1 - \text{ElecDHW}) \times \% \text{DHWD} \text{Displaced} \times (1 / \text{EF}_{\text{GAS BASE}} \times \text{GPD} \times \\ &\quad \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 1,000,000]\end{aligned}$$

Where:

⁴⁰⁰ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

⁴⁰¹ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

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$EF_{GAS\ EXIST}$ = Energy Factor (efficiency) of existing gas water heater
= Actual. If unknown assume efficiency is equal to pre 4/2015
Federal Standard:
= $(0.67 - 0.0019 \times \text{rated volume in gallons})^{402}$.
If size is unknown, assume 40 gallons; 0.594 EF

All other variables provided above

Illustrative Example – do not use as default assumption

Time of Sale:

For example, a GSHP with desuperheater is installed with a 40-gallon gas water heater in single family house in Baltimore

$$\begin{aligned}\Delta\text{MMBTU} &= [(1 - \text{ElecDHW}) \times \% \text{DHWD} \text{Displaced} \times (1 / EF_{GAS\ BASE} \times \text{GPD} \times \\ &\quad \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 1,000,000]] \\ &= [(1 - 0) \times 0.44 \times (((1/0.594) \times 17.6 \times 2.53 \times 365.25 \times 8.33 \times (125 - \\ &\quad 60.9) \times 1) / 1,000,000)] \\ &= 6.4 \text{ MMBTU}\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

⁴⁰² Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

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New Construction and Time of Sale: The lifecycle NPV incremental cost should be the actual installed cost of the Ground Source Heat Pump, including the ground loop and desuperheater, if installed, (default of \$3,957 per ton⁴⁰³), minus the assumed installed cost of the baseline equipment (\$838 per ton for ASHP⁴⁰⁴).

Measure Life

The expected measure life is assumed to be 20 years⁴⁰⁵.

Operation and Maintenance Impacts

N/A

⁴⁰³ Based on data provided to VEIC in 'Results of Home geothermal and air source heat pump rebate incentives documented by Illinois electric cooperatives'.

⁴⁰⁴ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

⁴⁰⁵ The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. <http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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High Efficiency Bathroom Exhaust Fan

Unique Measure Code(s): RS_HV_TOS_BTHFAN_0415

Effective Date: June 2015

End Date: TBD

Measure 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 20 CFM rated at a sound level of 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.

Definition of Baseline Condition

New standard efficiency (average CFM/Watt of 3.1⁴⁰⁶) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2⁴⁰⁷.

Definition of Efficient Condition

⁴⁰⁶ VEIC analysis looking at average baseline fan (i.e. non-Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

⁴⁰⁷ On/off cycling controls may be required of baseline fans larger than 50CFM.

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New efficient (average CFM/watt of 8.3⁴⁰⁸) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate (20 CFM) indicated by ASHRAE 62.2⁴⁰⁹

Annual Energy Savings Algorithm

$$\Delta kWh = (CFM * (1/\eta_{Baseline} - 1/\eta_{Efficient})/1000) * Hours$$

Where:

- CFM = Nominal Capacity of the exhaust fan
= 20 CFM⁴¹⁰
- $\eta_{Baseline}$ = Average efficacy for baseline fan
= 3.1 CFM/Watt⁴¹¹
- $\eta_{Efficient}$ = Average efficacy for efficient fan
= 8.3 CFM/Watt⁴¹²
- Hours = assumed annual run hours,
= 8760 for continuous ventilation.

⁴⁰⁸ VEIC analysis looking at average efficient fan (i.e. Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

⁴⁰⁹ Bi-level controls may be used by efficient fans larger than 50 CFM

⁴¹⁰ 20 CFM is used with continuous bathroom ventilation in ASHRAE 62.2. Note that 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.

⁴¹¹ VEIC analysis looking at average baseline fan (i.e. non-Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

⁴¹² VEIC analysis looking at average efficient fan (i.e. Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

$$\begin{aligned}\Delta \text{kWh} &= (20 * (1/3.1 - 1/8.3)/1000) * 8760 \\ &= 35.4 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = (\text{CFM} * (1/\eta_{\text{Baseline}} - 1/\eta_{\text{Efficient}})/1000) * \text{CF}$$

Where:

$$\begin{aligned}\text{CF} &= \text{Summer Peak Coincidence Factor} \\ &= 1.0 \text{ (continuous operation)}\end{aligned}$$

Other variables as defined above

$$\begin{aligned}\Delta \text{kW} &= (20 * (1/3.1 - 1/8.3)/1000) * 1.0 \\ &= 0.0040 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

For this time of sale measure, the incremental cost per installed fan is \$43.50⁴¹³.

⁴¹³ VEIC analysis using cost data collected from wholesale vendor;
<http://www.westsidewholesale.com/>.

Measure Life

The expected measure life is assumed to be 19 years⁴¹⁴.

Operation and Maintenance Impacts

N/A

⁴¹⁴ 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.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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ENERGY STAR Ceiling Fan

Unique Measure Code: RS_HV_TOS_ESCFN_0415, RS_HV_NC_ESCFN_0415
Effective Date: June 2015
End Date: TBD

Measure Description

A ceiling fan/light unit meeting the ENERGY STAR efficiency specifications is installed in place of a model meeting the federal standard. ENERGY STAR qualified ceiling fan/light combination units are over 60% more efficient than conventional fan/light units, and use improved motors and blade designs⁴¹⁵.

Due to the savings from this measure being derived from more efficient ventilation and more efficient lighting, and the loadshape and measure life for each component being very different, the savings are split in to the component parts and should be claimed together. Lighting savings should be estimated utilizing the ENERGY STAR Integrated Screw Based SSL screw-in measure.

Definition of Baseline Equipment

The baseline equipment is assumed to be a standard fan with EISA qualified incandescent or halogen light bulbs.

Definition of Efficient Equipment

The efficient equipment is defined as an ENERGY STAR certified ceiling fan with integral LED bulbs.

Annual Energy Savings Algorithm

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$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{Light}$$

$$\Delta kWh_{fan} = [Days * FanHours * ((\%Low_{base} * WattsLow_{base}) + (\%Med_{base} * WattsMed_{base}) + (\%High_{base} * WattsHigh_{base}))/1000] - [Days * FanHours * ((\%Low_{ES} * WattsLow_{ES}) + (\%Med_{ES} * WattsMed_{ES}) + (\%High_{ES} * WattsHigh_{ES}))/1000]$$

$$\Delta kWh_{light} = ((WattsBase - WattsEE)/1000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} - 1))$$

See ENERGY STAR Integrated Screw Based SSL screw-in measure (assume ISR = 1.0)

Where⁴¹⁶:

Days = Days used per year
= Actual. If unknown use 365.25 days/year

FanHours = Daily Fan "On Hours"
= Actual. If unknown use 3 hours

%Low_{base} = Percent of time spent at Low speed of baseline
= 40%

WattsLow_{base} = Fan wattage at Low speed of baseline
= Actual. If unknown use 15 watts

%Med_{base} = Percent of time spent at Medium speed of baseline
= 40%

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- WattsMed_{base}* = Fan wattage at Medium speed of baseline
= Actual. If unknown use 34 watts
- %High_{base}* = Percent of time spent at High speed of baseline
= 20%
- WattsHigh_{base}* = Fan wattage at High speed of baseline
= Actual. If unknown use 67 watts
- %Low_{ES}* = Percent of time spent at Low speed of ENERGY STAR
= 40%
- WattsLow_{ES}* = Fan wattage at Low speed of ENERGY STAR
= Actual. If unknown use 6 watts
- %Med_{ES}* = Percent of time spent at Medium speed of ENERGY STAR
= 40%
- WattsMed_{ES}* = Fan wattage at Medium speed of ENERGY STAR
= Actual. If unknown use 23 watts
- %High_{ES}* = Percent of time spent at High speed of ENERGY STAR
= 20%
- WattsHigh_{ES}* = Fan wattage at High speed of ENERGY STAR
= Actual. If unknown use 56 watts

For ease of reference, the fan assumptions are provided below in table form:

	Low Speed	Medium Speed	High Speed

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Percent of Time at Given Speed	40%	40%	20%
Conventional Unit Wattage	15	34	67
ENERGY STAR Unit Wattage	6	23	56
ΔW	9	11	11

If the lighting WattsBase and WattsEE is unknown, assume the following

$$\text{WattsBase} = 3 \times 43 = 129 \text{ W}$$

$$\text{WattsEE} = 1 \times 42 = 42 \text{ W}$$

Deemed savings if using defaults provided above:

$$\begin{aligned}\Delta \text{kWh}_{\text{fan}} &= [365.25 \times 3 \times ((0.4 \times 15) + (0.4 \times 34) + (0.2 \times 67))/1000] - \\ &\quad [365.25 \times 3 \times ((0.4 \times 6) + (0.4 \times 23) + (0.2 \times 56))/1000] \\ &= 36.2 - 25.0 \\ &= 11.2 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta \text{kWh}_{\text{light}} &= ((129 - 42)/1000) \times 1.0 \times 898 \times (0.899 + (1.09 - 1)) \\ &= 77.3 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\Delta \text{kWh} &= 11.2 + 77.3 \\ &= 88.5 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kW}_{\text{Fan}} + \Delta \text{kW}_{\text{light}}$$

$$\Delta \text{kW}_{\text{Fan}} = ((\text{WattsHigh}_{\text{base}} - \text{WattsHigh}_{\text{ES}})/1000) \times \text{CF}_{\text{fan}}$$

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$$\Delta kW_{\text{Light}} = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}_{\text{light}}$$

See General Purpose CFL Screw Based, Residential measure (assume ISR = 1.0)

Where:

$$\begin{aligned} CF_{\text{fan}_{SSP}} &= \text{Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)} \\ &= 0.31^{417} \end{aligned}$$

$$\begin{aligned} CF_{\text{fan}_{PJM}} &= \text{PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather} \\ &= 0.3^{418} \end{aligned}$$

CF_{light} = Summer Peak coincidence factor for lighting savings

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082 ⁴¹⁹
	PJM CF	0.084 ⁴²⁰

Deemed savings if using defaults provided above:

$$\begin{aligned} \Delta kW_{\text{fan ssp}} &= ((67-56)/1000) * 0.31 \\ &= 0.0034 \text{ kW} \end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{light ssp}} &= ((129 - 42)/1000) * 1.0 * 1.17 * 0.082 \\ &= 0.0083 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{ssp}} &= 0.0034 + 0.0083 \\ &= 0.012 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{fan pjm}} &= ((67-56)/1000) * 0.3 \\ &= 0.0033 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{light pjm}} &= ((129 - 42)/1000) * 1.0 * 1.18 * 0.084 \\ &= 0.0086 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{pjm}} &= 0.0033 + 0.0086 \\ &= 0.012 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

Heating penalty from improved lighting:

$$\begin{aligned}\Delta \text{MMBTUPenalty} &= - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF} * \\ &\quad 0.003412) / \eta_{\text{Heat}} * \% \text{FossilHeat}\end{aligned}$$

See General Purpose CFL Screw Based, Residential measure (assume ISR = 1.0)

Deemed savings if using defaults provided above:

$$\begin{aligned}\Delta \text{MMBTUPenalty} &= - (((129 - 42) / 1000) * 1.0 * 898 * 0.47 * 0.003412) / \\ &\quad 0.84) * 0.625 \\ &= -0.09\end{aligned}$$

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Annual Water Savings Algorithm
n/a

Incremental Cost
For this time of sale measure, the Incremental cost per unit is assumed to be \$46.⁴²¹

Measure Life
The measure life is assumed to be 15 years.

Operation and Maintenance Impacts
See the ENERGY STAR Integrated Screw Based SSL LED Measure.

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Domestic Hot Water (DHW) End Use

Low Flow Shower Head

Unique Measure Code(s): RS_WT_DI_SHWRHD_0519, RS_WT_TOS_SHWRHD_0519
Effective Date: June 2019
End Date: TBD

Measure Description

This measure relates to the installation of a low flow (≤2.0 GPM) showerhead in a home. This is a retrofit direct install measure or a new installation.

Definition of Baseline Condition

The baseline is a standard showerhead using 2.5 GPM. For direct install programs, utilities may choose to measure the actual flow rate of the existing showerhead and use that in the algorithm below

Definition of Efficient Condition

The efficient condition is an energy efficient shower head with a lower GPM flow than required by code. If baseline flow is not measured in the program, then the rated flow can be used for the efficient condition. However, if actual measured flow rates of the baseline fixtures are used in a direct install program, then the actual measured flow rate of the installed efficient aerators should be used as well.

Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta kWh^{422} = ((GPM_{base} - GPM_{low}) \times Time_{shower} \times \# \text{ people} \times Shower_{Person} \times \text{days/year} / ShowerHeads/home) \times 8.3 \times (TEMP_{sh} - TEMP_{in}) / DHW \text{ Recovery Efficiency} / 3,412$$

Where:

- GPM_{base}*

GPM_{low}

people
⁴²⁴

Time_{Shower}
Showers_{Person}
- = Gallons Per Minute of baseline showerhead*

= 2.5 ⁴²³ or actual flow rate if recorded

= Gallons Per Minute of low flow showerhead
= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.

= Number of people per household, if unknown, use 2.53

= 7.8 minutes⁴²⁵
= Average showers per person per day

⁴²² Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all showerhead installations.

⁴²³ The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

⁴²⁴ US Energy Information Administration, Residential Energy Consumption Survey; <https://www.eia.gov/consumption/residential/data/2015/hc/php/hc9.7.php>

⁴²⁵ Table 6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study compared shower length by single-family and multifamily populations, finding no statistical difference in showering times. For the energy-saving analysis, the study used the combined single-family and multifamily average shower length of 7.8 minutes. Per Pennsylvania TRM-2016

	=0.6 ⁴²⁶
days/year	= Days shower used per year
	= 365
ShowerHeads/home	= Average number of showers in the home
	= 1.3 ⁴²⁷
8.3	= Constant to convert gallons to lbs
TEMPsh	= Assumed temperature of water used for shower
	= 105
TEMPin	= Assumed temperature of water entering house
	= 60.9 ⁴²⁸
DHW Recovery Efficiency	= Recovery efficiency of electric water heater
	= 0.98 ⁴²⁹
3412	= Constant BTU per kWh

Illustrative example – do not use as default assumption

⁴²⁶ Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6. Per Pennsylvania TRM-2016

⁴²⁷ Table 9; Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013

⁴²⁸ Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

⁴²⁹ Electric water heater have recovery efficiency of 98%:
<http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>

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For a 2.0GPM rated showerhead:

$$\Delta \text{kWh} = ((2.5 - 2.0) \times 7.8 \times 2.53 \times 365 / 1.3) \times 8.3 \times (101 - 60.9) / .98 / 3412$$

$$= 276 \text{ kWh}$$

Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh/hours} * \text{CF}$$

Where:

$$\begin{aligned} \text{Hours} &= \text{Average number of hours per year spent using shower head} \\ &= \\ &= \text{Time}_{\text{Shower}} \times \# \text{ people} \times \text{Showers}_{\text{Person}} / 60 \times \text{days / year} \\ &= 7.8 \times 2.53 \times 0.6 / 60 \times 365 \\ &= 72 \text{ hours} \\ \text{CF} &= \text{Summer Peak Coincidence Factor for measure} \\ &= 0.0039^{430} \end{aligned}$$

⁴³⁰ Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
 9% * 7.8 minutes per day = 0.702 minutes
 0.702 / 180 (minutes in peak period) = 0.0039

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Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

$$\begin{aligned}\Delta kW &= 276 / 72 * 0.0039 \\ &= 0.015 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater:

$$\begin{aligned}\Delta \text{MMBTU} &= \\ &((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) \times \text{Time}_{\text{shower}} \times \# \text{ people} \times \text{Showers}_{\text{Person}} \times \\ &\quad \text{days/year} / \text{ShowerHeads/home}) \times 8.3 \times (\text{TEMP}_{\text{sh}} - \\ &\quad \text{TEMP}_{\text{in}}) / \text{Gas DHW Recovery Efficiency} / 10^6\end{aligned}$$

Where:

Gas DHW Recovery Efficiency = Recovery efficiency of gas water heater
= 0.80⁴³¹
All other variables As above

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

⁴³¹Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

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$$\begin{aligned}\Delta \text{MMBTU} &= ((2.5 - 2.0) \times 7.8 \times 2.53 \times 365 / 1.3) \times 8.3 \times (101 - 60.9) / \\ &\quad .80 / 10^6 \\ &= 1.23 \text{ MMBTU}\end{aligned}$$

Annual Water Savings Algorithm

$$\text{Water Savings} = ((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) \times \text{Time}_{\text{shower}} \times \# \text{ people} \times \text{Showers}_{\text{Person}} \times \text{days/year} / \text{ShowerHeads/home}) / 748$$

Where:

748 = Constant to convert from gallons to CCF
All other variables as above

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

$$\begin{aligned}\text{Water Savings} &= ((2.5 - 2.0) \times 7.8 \times 2.53 \times 365 / 1.3) / 748 \\ &= 3.7 \text{ CCF}\end{aligned}$$

kWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities' must be careful not to double count the monetary benefit of these savings within cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

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$$\Delta \text{kWh}_{\text{water}} = 2.07 \text{ kWh/CCF} * \Delta \text{Water (CCF)}$$

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

$$\begin{aligned} \Delta \text{kWh}_{\text{water}} &= 2.07 * 3.7 \\ &= 7.7 \text{ kWh} \end{aligned}$$

Incremental Cost

As a retrofit measure, the lifecycle NPV incremental cost will be the actual cost of installing the new showerhead. As a time of sale measure, the lifecycle NPV incremental cost is assumed to be \$2.⁴³²

Measure Life

The measure life is assumed to be 10 years.⁴³³

Operation and Maintenance Impacts

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

⁴³² Navigant Consulting, Ontario Energy Board, “Measures and Assumptions for Demand Side Management (DSM) Planning”, April 2009.

⁴³³ Consistent with assumptions provided on page C-6 of Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Faucet Aerators

Unique Measure Code(s): RS_WT_DI_FAUCET_0519 and RS_WT_TOS_FAUCET_0519
Effective Date: June 2019
End Date: TBD

Measure Description

This measure relates to the installation of a low flow (≤ 1.5 GPM) faucet aerator in a home. This could be a retrofit direct install measure or a new installation.

Definition of Baseline Condition

The baseline is a standard faucet aerator using 2.2 GPM. For direct install programs, utilities may choose to measure the actual flow rate of the existing aerator and use that in the algorithm below

Definition of Efficient Condition

The efficient condition is an energy efficient faucet aerator using rated GPM of the installed aerator. If actual flow rates of the baseline fixtures are used in a direct install program, then the actual flow rate of the installed aerators should be used as well.

Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta kWH^{434} = \frac{(((GPM_{base} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Time_{faucet} \times \#people \times \text{days/year} \times DR) \times 8.3 \times (Temp_{ft} - Temp_{in}) / \text{DHW Recovery Efficiency}}{3412}$$

Where:

GPM_{base} = Gallons Per Minute of baseline faucet
 = 2.2⁴³⁵ or actual flow rate if recorded

GPM_{low} = Gallons Per Minute of low flow faucet
 = Rated flow rate of unit installed or actual flow rate if baseline flow rate used.

people = Average number of people per household
 = 2.53⁴³⁶

Time_{kitchenfaucet} = 4.5 minutes⁴³⁷

Time_{bathfaucet} = 1.6 minutes

gals/day/person = Average gallons per day used by faucet per person
 = *Time_{faucet}* * *GPM_{base}*
 = if unknown, use 6.1

⁴³⁴ Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.

⁴³⁵ In 1998, the Department of Energy adopted a maximum flow rate standard of 2.2 gpm at 60 psi for all faucets: 63 Federal Register 13307; March 18, 1998.

⁴³⁶ US Energy Information Administration, Residential Energy Consumption Survey; <https://www.eia.gov/consumption/residential/data/2015/hc/php/hc9.7.php>

⁴³⁷ Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. If aerator location is known, use the corresponding kitchen/bathroom value. If unknown, use 3 min/person/day as the average length of use value, which is the total for the household: kitchen (4.5 min/person/day) + bathroom (1.6 min/person/day) = 6.1 min/person/day/2. Via Pennsylvania TRM

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days/y = Days faucet used per year

= 365

DR = Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)

= 50% for kitchens, 70% for bathrooms

Throttle_{base} = 83%

Throttle_{low} = 95%⁴³⁸

8.3 = Constant to convert gallons to lbs

TEMP_{ft} = Assumed temperature of water used by faucet

= 93 kitchen, 86 bathrooms

TEMP_{in} = Assumed temperature of water entering house

= 60.9⁴³⁹

DHW Recovery Efficiency = Recovery efficiency of electric water heater

= 0.98⁴⁴⁰

0.003412 = Constant to converts MMBTU to kWh

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator in a kitchen:

$$\Delta \text{kWh} = (((2.2 \times .83) - (1.5 \times .950)) \times 4.5 \times 2.53 \times 365 \times .5) \times 8.3 \times (93 - 60.9) / 0.98 / 3412$$

⁴³⁸ 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.

⁴³⁹ Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential Retrofit Programs." April 4, 2014, Appendix E, page 66.

⁴⁴⁰ See <http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>

$$= 66.4 \text{ kWh}$$

Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/hours * CF$$

Where:

$$\begin{aligned} \text{Hours} &= \text{Average number of hours per year spent using faucet} \\ &= \#people \times Time_{faucet} / 60 * 365 \\ &= 2.53 \times 4.5 / 60 * 365 \\ &= 69 \text{ hours} \\ CF &= \text{Summer Peak Coincidence Factor for measure} \\ &= 0.00262^{441} \end{aligned}$$

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\Delta kW = 44 / 46 * 0.00262$$

⁴⁴¹ Calculated as follows: Assume 13% faucet use takes place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
13% * 3.6 minutes per day (10.9 * 2.56 / 3.5 / 2.2 = 3.6) = 0.47 minutes
= 0.47 / 180 (minutes in peak period) = 0.00262

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= 0.025 kW

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater, MMBTU savings provided below:

$$\Delta \text{MMBTU} = (((\text{GPM}_{\text{base}} \times \text{Throttle}_{\text{base}}) - (\text{GPM}_{\text{low}} \times \text{Throttle}_{\text{low}})) \times \text{Time}_{\text{faucet}} \times \text{\#people} \times \text{days/year} \times \text{DR}) \times 8.3 \times (\text{Temp}_{\text{ft}} - \text{Temp}_{\text{in}}) / \text{DHW Recovery Efficiency} / 10^6$$

Where:

Gas DHW Recovery Efficiency = *Recovery efficiency of gas water heater*
= 0.80⁴⁴²
All other variables As above

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator in a kitchen:

$$\Delta \text{MMBTU} = (((2.2 \times .83) - (1.5 \times .950)) \times 4.5 \times 2.53 \times 365 \times .5) \times 8.3 \times (93 - 60.9) / 0.75 / 10^6$$

= 0.296 MMBTU

Annual Water Savings Algorithm

$$\text{Water Savings} = ((\text{GPM}_{\text{base}} \times \text{Throttle}_{\text{base}}) - (\text{GPM}_{\text{low}} \times \text{Throttle}_{\text{low}})) \times \text{Time}_{\text{faucet}} \times \text{\#people} \times \text{days/year} \times \text{DR} / 748$$

⁴⁴² Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

Where:

748 = Constant to convert from gallons to CCF
All other variables same as above

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator installed in a kitchen:

$$\text{Water Savings} = ((2.2 \times .83) - (1.5 \times .950)) \times 4.6 \times 2.53 \times 365 \times .5 / 748$$

$$= 1.114 \text{ CCF}$$

kWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities' must be careful not to double count the monetary benefit of these savings within cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

$$\Delta \text{kWh}_{\text{water}}^{443} = 2.07 \text{ kWh/CCF} \times \Delta \text{Water (CCF)}$$

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\begin{aligned} \Delta \text{kWh}_{\text{water}} &= 2.07 \text{ kWh/CCF} \times 0.743 \text{ CCF} \\ &= 2.79 \text{ kWh} \end{aligned}$$

⁴⁴³ This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

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Incremental Cost

As a retrofit measure, the incremental cost will be the actual cost of installing the new aerator. As a time of sale measure, the incremental cost is assumed to be \$2.⁴⁴⁴

Measure Life

The measure life is assumed to be 10 years.⁴⁴⁵

Operation and Maintenance Impacts

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

⁴⁴⁴ Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.

⁴⁴⁵ California DEER Effective Useful Life (EUL) Table - 2014 Update

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Domestic Hot Water Tank Wrap

Unique Measure Code(s): RS_WT_RF_HWWRAP_0113
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to a Tank Wrap or insulation “blanket” that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated.

Definition of Baseline Condition

The baseline condition is a standard electric domestic hot water tank without an additional tank wrap.

Definition of Efficient Condition

The efficient condition is the same standard electric domestic hot water tank with an additional tank wrap.

Annual Energy Savings Algorithm

$$\Delta kWh = ((U_{base}A_{base} - U_{insul}A_{base}) * \Delta T * \text{Hours}) / (3412 * \eta_{DHW})$$

Where:

- ΔkWh

= Gross customer annual kWh savings for the measure
- U_{base}
- = Overall heat transfer coefficient prior to adding tank wrap (BTU/Hr-F-ft²)

<i>U_{insul}</i>	<i>= See table below. If unknown assume 1/8 ⁴⁴⁶</i> <i>= Overall heat transfer coefficient after addition of tank wrap (BTU/Hr-F-ft²)</i>
<i>A_{base}</i>	<i>= See table below. If unknown assume 1/18 ⁴⁴⁷</i> <i>= Surface area of storage tank prior to adding tank wrap (square feet)</i>
<i>A_{insul}</i>	<i>= See table below. If unknown assume 23.18 ⁴⁴⁸</i> <i>= Surface area of storage tank after addition of tank wrap (square feet)</i>
<i>ΔT</i>	<i>= See table below. If unknown assume 25.31 ⁴⁴⁹</i> <i>= Average temperature difference between tank water and outside air temperature (°F)</i>
<i>Hours</i>	<i>= 60°F ⁴⁵⁰</i> <i>= Number of hours in a year (since savings are assumed to be constant over year).</i>
<i>3412</i>	<i>= 8760</i> <i>= Conversion from BTU to kWh</i>
<i>η_{DHW}</i>	<i>= Recovery efficiency of electric hot water heater</i> <i>= 0.98 ⁴⁵¹</i>

⁴⁴⁶ Assumptions are from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM) for a poorly insulated 40 gallon tank

⁴⁴⁷ Assumes an R-10 tank wrap is added.

⁴⁴⁸ Assumptions from PA TRM for a 40-gallon tank. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

⁴⁴⁹ Ibid.

⁴⁵⁰ Assumes 125° F water leaving the hot water tank and average temperature of basement of 65° F.

⁴⁵¹ NREL, National Residential Efficiency Measures Database, <http://www.nrel.gov/ap/retrofits/measures.cfm?gld=6&ctld=40>

The following table has default savings for various tank capacity and pre and post R-VALUES.

Capacity (gal)	Rbase	Rinsul	Abase (ft2)	ΔkWh	ΔkW
30	8	16	19.16	171	0.019
30	10	18	19.16	118	0.014
30	12	20	19.16	86	0.010
30	8	18	19.16	194	0.022
30	10	20	19.16	137	0.016
30	12	22	19.16	101	0.012
40	8	16	23.18	207	0.024
40	10	18	23.18	143	0.016
40	12	20	23.18	105	0.012
40	8	18	23.18	234	0.027
40	10	20	23.18	165	0.019
40	12	22	23.18	123	0.014
50	8	16	24.99	225	0.026
50	10	18	24.99	157	0.018
50	12	20	24.99	115	0.013
50	8	18	24.99	255	0.029
50	10	20	24.99	180	0.021
50	12	22	24.99	134	0.015
80	8	16	31.84	290	0.033
80	10	18	31.84	202	0.023
80	12	20	31.84	149	0.017
80	8	18	31.84	327	0.037
80	10	20	31.84	232	0.027

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80	12	22	31.84	173	0.020

If tank specifics are unknown assume 40 gallons as an average tank size⁴⁵², and savings from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kWh = ((23.18/8 - 23.18/18) * 60 * 8760) / (3412 * 0.98)$$
$$= 253 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / 8760$$

Where:

ΔkWh
8760

= kWh savings from tank wrap installation
= Number of hours in a year (since savings are assumed to be constant over year).

The table above has default savings for various tank capacity and pre and post R-VALUES.

If tank specifics are unknown assume 40 gallons as an average tank size⁴⁵³, and savings are from adding R-10 to a poorly insulated R-8 tank:

⁴⁵² DOE, “Residential Heating Products Final Rule Technical Support Document,” Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

⁴⁵³ DOE, “Residential Heating Products Final Rule Technical Support Document,” Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

$$\Delta kW = 253 / 8760$$
$$= 0.029 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental cost for this retrofit measure is the actual cost of installing the tank wrap. If unknown assume \$35 average cost.⁴⁵⁴

Measure Life
The measure life is assumed to be 5 years.⁴⁵⁵

Operation and Maintenance Impacts
n/a

⁴⁵⁴ Based on VEIC online product review.
⁴⁵⁵ Conservative estimate that assumes the tank wrap is installed on an existing unit with 5 years remaining life.

DHW Pipe Insulation

Unique Measure Code: RS_WT_RF_PIPEIN_0711

Effective Date: June 2014

End Date: TBD

Measure Description

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first elbow of the hot water carrying pipe.

Note, the algorithm provided to calculate savings may be used to determine an appropriate deemed savings value if the programs can provide appropriate average values for each of the variables.

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is un-insulated hot water carrying copper pipes.

Definition of Efficient Condition

To efficiency case is installing pipe wrap insulation to the first elbow of the hot water carrying copper pipe.

Annual Energy Savings Algorithm

If electric domestic hot water tank:

$$\Delta kWh = ((1/R_{exist} - 1/R_{new}) * (L * C) * \Delta T * 8,760) / \eta_{DHW} / 3413$$

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Where:

R_{exist} = Assumed R-value of existing uninsulated piping
= 1.0⁴⁵⁶
 R_{new} = R-value of existing pipe plus installed insulation
= Actual
Length = Length of piping insulated
= Actual
Circumference = Circumference of piping
= Actual (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)
 ΔT = Temperature difference between water in pipe and ambient air
= 65°F⁴⁵⁷
8,760 = Hours per year
 η_{DHW} = DHW Recovery efficiency (η_{DHW})
= 0.98⁴⁵⁸
3413 = Conversion from BTU to kWh

Illustrative example – do not use as default assumption
Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

⁴⁵⁶ Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77, presented to the Ontario Energy Board:

http://www.oeb.gov.on.ca/OEB/Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

⁴⁵⁷ Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.

⁴⁵⁸ Electric water heaters have recovery efficiency of 98%:
<http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>

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$$\Delta \text{kWh} = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8,760) / 0.98 / 3,413$$

$$= 104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh} / 8,760$$

Illustrative example – do not use as default assumption
 Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta \text{kW} = 104 / 8,760$$

$$= 0.012 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel DHW unit:

$$\Delta \text{MMBTU} = ((1/R_{\text{exist}} - 1/R_{\text{new}}) * (L * C) * \Delta T * 8,760) / \eta_{\text{DHW}} / 1,000,000$$

Where:

$$\eta_{\text{DHW}} = \text{Recovery efficiency of gas hot water heater}$$

$$= 0.75^{459}$$

Illustrative example – do not use as default assumption

⁴⁵⁹ Review of AHRI Directory suggests range of recovery efficiency ratings for *new* Gas DHW units of 70-87%. Average of *existing* units is estimated at 75%

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Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta \text{MMBTU} = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8,760) / 0.75 / 1,000,000$$
$$= 0.46 \text{ MMBTU}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure should be the actual cost of material and labor. If this is not available, assume \$3 per foot of insulation⁴⁶⁰.

Measure Life

The measure life is assumed to be 15 years⁴⁶¹.

Operation and Maintenance Impacts

n/a

⁴⁶⁰ Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

⁴⁶¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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High Efficiency Gas Water Heater

Unique Measure Code: RS_WT_TOS_GASDHW_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes the purchase of a high efficiency gas water heater meeting or exceeding ENERGY STAR criteria for the water heater category provided below, in place of a new unit rated at the minimum Federal Standard. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a new conventional gas storage water heater rated at the federal minimum⁴⁶².

For 20 - 55 gallons: EF = 0.6483 – (0.0017 * rated volume in gallons)
For 55 - 100 gallons: EF = 0.7897 – (0.0004 * rated volume in gallons)

If size is unknown, assume 40 gallons; 0.580 EF.

Definition of Efficient Condition

⁴⁶² U.S. Code of Federal Regulations at 10 CFR 430.32(d) (2021). Assumes “Medium” draw pattern.

The efficient condition is a new high efficiency gas water heater meeting or exceeding the minimum efficiency Energy Star qualification criteria provided below⁴⁶³:

Water Heater Type		Energy Factor
High Efficiency Gas Storage	<= 55 gallons	0.67
	> 55 gallons	0.77
Gas Tankless		0.90

Annual Energy Savings Algorithm
n/a

Summer Coincident Peak kW Savings Algorithm
n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta\text{MMBTU} = (1/\text{EF}_{\text{base}} - 1/\text{EF}_{\text{efficient}}) * (\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{in}}) * 1.0)/1,000,000$$

Where:

EF_Baseline = Energy Factor rating for baseline equipment

⁴⁶³
https://www.energystar.gov/sites/default/files/Water%20Heaters%20Final%20Version%203.2_Program%20Requirements.pdf

For <=55 gallons: 0.6483 – (0.0017 * rated volume in gallons)
For > 55 gallons: 0.7897 – (0.0004 * rated volume in gallons)

= If tank size unknown assume 40 gallons and EF_Baseline of 0.580

EF_Efficient = Energy Factor Rating for efficient equipment

= Actual. If Tankless whole-house multiply rated efficiency by 0.91⁴⁶⁴. If unknown assume values in look up in table below

Water Heater Type		EF_Efficient
Gas Storage	<=55 gallons	0.67
	> 55 gallons	0.77
Gas Tankless		0.90 * 0.91 = 0.82

GPD = Gallons Per Day of hot water use per person

⁴⁶⁴ The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. “Field and Laboratory Testing of Tankless Gas Water Heater Performance” Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

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	= 45.5 gallons hot water per day per household/2.53 people per household ⁴⁶⁵
	= 17.6
Household	= Average number of people per household
	= 2.53 ⁴⁶⁶
365.25	= Days per year, on average
γ_{Water}	= Specific Weight of water
	= 8.33 pounds per gallon
T_{out}	= Tank temperature
	= 125°F
T_{in}	= Incoming water temperature from well or municipal system
	= 60.9 ⁴⁶⁷
1.0	= Heat Capacity of water (1 BTU/lb*°F)

⁴⁶⁵ US Energy Information Administration, Residential Energy Consumption Survey 2009; <http://www.eia.gov/consumption/residential/data/2009/xls/HC9.10%20Household%20Demographics%20in%20South%20Region.xls>

⁴⁶⁶ Ibid

⁴⁶⁷ Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

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Illustrative example – do not use as default assumption
For example, installing a 40 gallon condensing gas storage water heater, with an energy factor of 0.82 in a single family house:

$$\Delta \text{MMBTU} = (1/0.580 - 1/0.82) * (17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1) / 1,000,000$$
$$= 4.38 \text{ MMBTU}$$

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental cost for this time of sale measure is dependent on the type of water heater as listed below.

Water heater Type	Incremental Cost
Non-condensing gas Storage	\$159 ⁴⁶⁸
Condensing gas storage	\$685 ⁴⁶⁹

⁴⁶⁸ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.
⁴⁶⁹ Source for cost info; DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14 (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf)

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Tankless whole-house unit	\$407 ⁴⁷⁰

Measure Life
The measure life is assumed to be 13 years⁴⁷¹.

Operation and Maintenance Impacts
n/a

⁴⁷⁰ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

⁴⁷¹ Based on ACEEE Life-Cycle Cost analysis; <http://www.aceee.org/node/3068#lcc>

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Heat Pump Domestic Water Heater

Unique Measure Code(s): RS_WT_TOS_HPRSHW_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure relates to the installation of a Heat Pump domestic water heater with power input rating of $\leq 12\text{kW}$ ⁴⁷² in place of a standard electric water heater in conditioned space. This is a time of sale measure.

Definition of Baseline Condition

Unless otherwise excepted⁴⁷³, the baseline condition is assumed to be a new electric water heater meeting federal minimum efficiency standards effective December 29, 2016⁴⁷⁴. Use Efficiency Criteria Table below to calculate EF.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified heat pump water heater⁴⁷⁵.

⁴⁷² [CFR 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.2](#)

⁴⁷³ The federal minimum standard for water heaters >55 gallon was increased to $\text{EF} \geq 2.0$, compared to an $\text{EF} \geq 0.907$ for water heaters smaller than 55 gallons. Since the standard went into effect, sales of the larger units have declined dramatically. Evaluators in Maryland hypothesize that customers are using a variety of strategies to avoid the higher efficiency standard, including: combining multiple smaller water heaters, increasing set points on smaller heaters, etc. To address this concern, some TRM stakeholders recommended that a common practice baseline be used for this measure, rather than the minimum federal standard. However, to be consistent with other measures in the Mid-Atlantic TRM, the decision was made to use the federal minimum efficiency standard baseline, recognizing that individual jurisdictions may depart from the federal standard baseline and use a common practice baseline instead.

⁴⁷⁴ [Docket No. EERE-2015-BT-TP-0007](#)

⁴⁷⁵ [ENERGY STAR® v3.2 Program Requirements for Residential Water Heaters](#)

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Consumer Electric Storage Water Heater Efficiency Criteria						
ENERGY STAR allows for qualification with EF or UEF (see ES v3.2 Specs)			Uniform Energy Factor (UEF) - based on draw pattern			
Condition	Rated Storage Volume (Vs)	Energy Factor (EF) 2015 standard	very small 10GPD	low 38GPD	medium 55GPD	high 84GPD
Base	≥20 and ≤55 gal	0.960- (0.0003 × Vs)	0.8808 – (0.0008 × Vs)	0.9254 – (0.0003 × Vs)	0.9307 – (0.0002 × Vs)	0.9349 – (0.0001 × Vs)
	>55 gal and ≤120 gal	2.057- (0.00113 × Vs)	1.9236 – (0.0011 × Vs)	2.0440 – (0.0011 × Vs)	2.1171 – (0.0011 × Vs)	2.2418 – (0.0011 × Vs)
Efficient	≤55 gal	2.0	NA	NA	2.0	2.0
	>55	2.2	NA	NA	2.2	2.2

Determining Draw Pattern

The relevant hot water draw pattern is specific to usage at the installed location. If actual draw pattern is not known, it can be estimated from the water heater's first hour rating⁴⁷⁶ per table below.

If first hour rating is unknown, use medium draw pattern with rated storage capacity ≤50 gallons, and high draw pattern if >50 gallons.⁴⁷⁷

Draw Pattern based on First Hour Rating

⁴⁷⁶ [CFR part 430 App E 5.4.1](#)

⁴⁷⁷ [Title 10 → Chapter II → Subchapter D → Part 430 → E → Table 5.4.1](#)

First Hour Rating	Draw Pattern
<18 gallons	Very Small
=18 and <51 gallons	Low
=51 and <75 gallons	Medium
≥75 gallons	High

Annual Energy Savings Algorithm

$$\Delta kWh = MMBTU/yr * UEF_{BASE} * (1/UEF_{BASE} - 1/UEF_{EFFICIENT}) * 293 + kWh_{cooling} - kWh_{heating}$$

Where:

- UEF_{BASE}
= Uniform Energy Factor (efficiency) of standard electric water heater based on minimum federal standards, per efficiency criteria table above.
- $UEF_{EFFICIENT}$
= Uniform Energy Factor of efficient, installed Heat Pump water heater
= Actual
- 293
= Conversion from MMBTU to kWh
- $MMBTU/yr$
= existing annual water heating energy consumed, actual (measured or calculated)

OR, if unknown, by disaggregation:
$$= GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{in}) * 1.0 / 3412$$
- GPD
= Gallons Per Day of hot water use per person

	<i>= 45.5 gallons hot water per day per household/2.48⁴⁷⁸ people per household</i>
	<i>= 18.35</i>
<i>Household</i>	<i>= Average number of people per household</i>
	<i>= 2.48</i>
<i>365.25</i>	<i>= Days per year</i>
<i>γ_{Water}</i>	<i>= Specific weight of water</i>
	<i>= 8.33 pounds per gallon</i>
<i>T_{OUT}</i>	<i>= Tank temperature</i>
	<i>= 125°F</i>
<i>T_{IN}</i>	<i>= Incoming water temperature from well or munipcle system</i>
	<i>= 60.9⁴⁷⁹</i>
<i>1.0</i>	<i>= Heat Capacity of water (1 BTU/lb*°F)</i>
<i>3412</i>	<i>= Conversion from BTU to kWh</i>

⁴⁷⁸ US Energy Information Administration, Residential Energy Consumption Survey 2015; [EIA RECS demographics for South Atlantic regions](#)

⁴⁷⁹ Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

kWh_cooling⁴⁸⁰ = Cooling savings from conversion of heat in home to water heat

$$= (((1/UEF_{NEW} * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412) * LF * 33\% / COP_{COOL})$$

Where:

- LF

= Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location

= 0.0 for installation in an unconditioned space
- 33%

= Portion of removed heat that results in cooling savings⁴⁸¹
- COP_{COOL}

= COP of central air conditioning

= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

⁴⁸⁰ This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling and latent cooling demands.

⁴⁸¹ REMRate determined percentage (33%) of lighting savings that result in reduced cooling loads for several different building configurations in Wilmington, DE, Baltimore, MD and Washington, DC (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

kWh_heating = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

For Natural Gas heating, kWh_heating = 0

For electric heating:

$$= (((1/UEF_{NEW} * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 47\%) / COP_{HEAT}$$

- Where:
- 47% = Portion of removed heat that results in increased heating load⁴⁸²
 - COP_{HEAT} = COP of electric heating system
 - = actual. If not available, use⁴⁸³.

System Type	Age of Equipment	HSPF Estimate	COP _{HEAT} (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006 - 2014 (default)	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00

⁴⁸² REMRate determined percentage (47%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

⁴⁸³ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

Prescriptive savings based on defaults provided above:

$$\Delta \text{kWh electric resistance heat} = (((1/0.945 - 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) + \text{kWh\_cooling} - \text{kWh\_heating}$$

$$\text{kWh\_cooling} = ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) * 0.5 * 0.33 / 3.08 * 1.33$$

$$= 90.7 \text{ kWh}$$

$$\text{kWh\_heating} = ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) * 0.5 * 0.47 / 1.0$$

$$= 299.1 \text{ kWh}$$

$$\Delta \text{kWh electric resistance heat} = 1420.7 + 90.7 - 299.1$$

$$= 1212.3 \text{ kWh}$$

$$\Delta \text{kWh heat pump heat} = (((1/0.945 - 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) + \text{kWh\_cooling} - \text{kWh\_heating}$$

$$\text{kWh\_cooling} = 90.7 \text{ kWh}$$

$$\text{kWh\_heating} = ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) * 0.5 * 0.47 / 2.0$$

$$= 149.5 \text{ kWh}$$

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$$\begin{aligned}\Delta \text{kWh heat pump heat} &= 1420.7 + 90.7 - 149.5 \\ &= 1361.9 \text{ kWh}\end{aligned}$$

$$\Delta \text{kWh fossil fuel heat} = (((1/0.945 - 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) + \text{kWh\_cooling} - \text{kWh\_heating}$$

$$\text{kWh\_cooling} = 90.7$$

$$\text{kWh\_heating} = 0$$

$$\begin{aligned}\Delta \text{kWh fossil fuel heat} &= 1420.7 + 90.7 - 0 \\ &= 1511.4 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = 0.17 \text{ kW}^{484}$$

Annual Fossil Fuel Savings Algorithm

$$\begin{aligned}\Delta \text{MMBTU} &= - (((1/ \text{UEF}_{\text{NEW}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * \\ &1.0) / 3412) * \text{LF} * 47\% * 0.003412) / (\eta_{\text{Heat}} * \% \text{ Natural Gas})\end{aligned}$$

Where:

⁴⁸⁴ Based on a chart showing summer weekday average electrical demand on page 10 of FEMP Study “Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters” (http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf). Using data points from the chart, the average delta kW in heat pump mode during the peak hours compared to resistance mode is 0.17kW.

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Δ MMBTU = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat.⁴⁸⁵

0.003412 = conversion factor (MMBTU per kWh)

η Heat = Efficiency of heating system

= Actual.⁴⁸⁶ If not available, use 84%.⁴⁸⁷

% Natural Gas = Factor dependent on heating fuel:

Heating System	%Natural Gas
Electric resistance or heat pump	0%
Natural Gas	100%
Unknown heating fuel ⁴⁸⁸	62.5%

⁴⁸⁵ This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater.

⁴⁸⁶ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (<http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>) or by performing duct blaster testing.

⁴⁸⁷ This has been estimated assuming typical efficiencies of existing heating systems weighted by percentage of homes with non-electric heating (based on Energy Information Administration, 2009 Residential Energy Consumption Survey: <http://www.eia.gov/consumption/residential/data/2009/xls/HC6.9%20Space%20Heating%20in%20Midwest%20Region.xls>).

⁴⁸⁸ Based on KEMA baseline study for Maryland.

Other factors as defined above

Prescriptive savings based on defaults provided above:

ΔMMBTU for fossil fuel heated homes:

$$\begin{aligned} \Delta \text{MMBTU} &= - ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / \\ &\quad 3412)) * 0.5 * 0.47 * 0.003412) / (0.72 * 1.0) \\ &= - 1.21 \text{MMBTU} \end{aligned}$$

Annual Water Savings Algorithm
n/a

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Incremental Cost

The lifecycle NPV incremental cost for the time of sale measure is provided below.

Size	Uniform Efficiency Factor	Incremental Cost per Unit
40 Gallon Heat Pump Water Heater	2.0	\$1393 ⁴⁸⁹
60 Gallon Heat Pump Water Heater	2.7	\$460 ⁴⁹⁰

Measure Life

The expected measure life is assumed to be 13 years.⁴⁹¹

Operation and Maintenance Impacts

n/a

⁴⁸⁹ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation to 2019 and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

⁴⁹⁰ NEEP Water Heating, Boiler and Furnace Cost Study September 2018, adjusted to 2019 dollars. Baseline is a unit with UEF of 2.16

⁴⁹¹ DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Page 8-52 http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

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Thermostatic Restrictor Shower Valve

Unique Measure Code: RS_HV_RF_GSHPS_0415, RS_HV_NC_GSHPS_0415
Effective Date: June 2015
End Date: TBD

Measure Description

The measure is the installation of a thermostatic restrictor shower valve in a single or multi-family household. This is a valve attached to a residential showerhead which restricts hot water flow through the showerhead once the water reaches a set point (generally 95F or lower).
This measure was developed to be applicable to the following program types: RF, NC, DI. If applied to other program types, the measure savings should be verified.

Definition of Baseline Condition

The baseline equipment is the residential showerhead without the restrictor valve installed.

Definition of Efficient Condition

To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

Annual Energy Savings Algorithm

$$\Delta kWh$$

$$= \%ElectricDHW * ((GPM\_base\_S * L\_showerdevice) * Household * SPCD * 365.25 / SPH) * EPG\_electric$$

Where:

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%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	24% ⁴⁹²

GPM_base_S = Flow rate of the basecase showerhead, or actual if available

Program	GPM
Direct-install, device only	2.5 ⁴⁹³
New Construction or direct install of device and low flow showerhead	Rated or actual flow of program-installed showerhead

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

⁴⁹² Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic Region. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

⁴⁹³ The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

	<i>= 0.89 minutes⁴⁹⁴</i>
<i>Household</i>	<i>= Average number of people per household</i>
	<i>= 2.56⁴⁹⁵</i>
<i>SPCD</i>	<i>= Showers Per Capita Per Day</i>
	<i>= 0.6⁴⁹⁶</i>
<i>365.25</i>	<i>= Days per year, on average.</i>
<i>SPH</i>	<i>= Showerheads Per Household so that per-showerhead savings fractions can be determined</i>
	<i>= 1.6⁴⁹⁷</i>

⁴⁹⁴ Average of the following sources: ShowerStart LLC survey; “Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart”, City of San Diego Water Department survey; “Water Conservation Program: ShowerStart Pilot Project White Paper”, and PG&E Work Paper PGECODHW113.

⁴⁹⁵ US Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

⁴⁹⁶ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

⁴⁹⁷ Estimate based on review of a number of studies:

a. Pacific Northwest Laboratory; “Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications” <http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?puurl=/10185385-CEkZMk/native/>

b. East Bay Municipal Utility District; “Water Conservation Market Penetration Study” http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

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EPG_{electric} = Energy per gallon of hot water supplied by electric

= $(8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_{electric} * 3412)$

= $(8.33 * 1.0 * (105 - 60.9)) / (0.98 * 3412)$

= 0.11kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (BTU/lb-°)

ShowerTemp = Assumed temperature of water

= 105F ⁴⁹⁸

SupplyTemp = Assumed temperature of water entering house

= 60.9 ⁴⁹⁹

RE_{electric} = Recovery efficiency of electric water heater

⁴⁹⁸ Based on “Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems”, Jim Lutz, Lawrence Berkeley National Laboratory, September 2011.

⁴⁹⁹ Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

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$$= 98\%^{500}$$

$$3412 = \text{Constant to convert BTU to kWh}$$

Illustrative Example - do not use as default assumption

For example, a direct installed valve in a home with electric DHW:

$$\begin{aligned}\Delta \text{kWh} &= 1.0 * (2.5 * 0.89 * 2.56 * 0.6 * 365.25 / 1.6) * 0.11 \\ &= 86 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh/Hours} * \text{CF}$$

Where:

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

$$= ((\text{GPM\_base\_S} * \text{L\_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * 0.746^{501} / \text{GPH}$$

GPH = Gallons per hour recovery of electric water heater calculated for 59.1 temp rise (120-60.9), 98% recovery

⁵⁰⁰ Electric water heaters have recovery efficiency of 98%:

<http://www.ahridirectory.org/ahridirectory/pages/home.aspx>

⁵⁰¹ 74.6% is the proportion of hot 120F water mixed with 60.1F supply water to give 105F shower water.

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efficiency, and typical 4.5kW electric resistance storage tank.

$$= 30.0$$

$$\text{Hours} = ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.746 / 30$$

$$= 19.4 \text{ hours}$$

$$CF = \text{Coincidence Factor for electric load reduction}$$

$$= 0.0015^{502}$$

Illustrative example – do not use as default assumption

For example, a direct installed valve in a home with electric DHW:

$$\Delta kW = 86 / 19.4 * 0.0015$$

$$= 0.007 \text{ kW}$$

⁵⁰² Calculated as follows: Assume 11% showers take place during peak hours (based on: <http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282001%29-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf>). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is $0.11 * 65 / 365 = 1.96\%$. The number of hours of recovery during peak periods is therefore assumed to be $1.96\% * 19.4 = 0.38$ hours of recovery during peak period, where 19.4 equals the annual electric DHW recovery hours for showerhead use prevented by the device. There are 260 hours in the peak period so the probability you will see savings during the peak period is $0.38 / 260 = 0.0015$

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Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBTU} = \% \text{FossilDHW} * ((\text{GPM\_base\_S} * \text{L\_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{EPG\_gas}$$

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	76% ⁵⁰³

$$\begin{aligned} \text{EPG\_gas} &= \text{Energy per gallon of Hot water supplied by gas} \\ &= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE\_gas} * 1,000,000) \\ &= 0.00065 \text{ MMBTU/gal} \end{aligned}$$

RE_gas= Recovery efficiency of gas water heater

⁵⁰³ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic Region. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

= 75% For SF homes⁵⁰⁴

1,000,000 = Converts BTUs to MMBTU

Other variables as defined above.

Illustrative example – do not use as default assumption

For example, a direct installed valve in a home with gas DHW:

$$\begin{aligned}\Delta\text{MMBTU} &= 1.0 * ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.00065 \\ &= 0.51 \text{ MMBTU}\end{aligned}$$

Water impact Descriptions and calculations

$$\Delta\text{CCF} = ((\text{GPM\_base\_S} * \text{L\_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) / 748$$

Where:

748 = Constant to convert from gallons to CCF

Other variables as defined above

Illustrative example – do not use as default assumption

For example, a direct installed valve:

⁵⁰⁴ DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

$$\begin{aligned}\Delta\text{CCF} &= ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) / 748 \\ &= 1.0 \text{ CCF}\end{aligned}$$

Measure Life

The expected measure life is assumed to be 10 years.⁵⁰⁵

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is the actual measure cost or \$30⁵⁰⁶ if not available.

Operation and Maintenance Impacts

N/A

⁵⁰⁵ Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead

⁵⁰⁶ Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

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Water Heater Temperature Setback

Unique Measure Code: RS_WT_RF_WHTSB_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to turning down an existing hot water tank thermostat setting that is at 130 degrees or higher. Savings are provided to account for the resulting reduction in standby losses. This is a retrofit measure.

Definition of Baseline Equipment

The baseline condition is a hot water tank with a thermostat setting that is 130 degrees or higher. Note if there are more than one DHW tanks in the home at or higher than 130 degrees and they are all turned down, then the savings per tank can be multiplied by the number of tanks.

Definition of Efficient Equipment

The efficient condition is a hot water tank with the thermostat reduced to no lower than 120 degrees.

Annual Energy Savings Algorithm

For homes with electric DHW tanks:

$\Delta kWh^{507} = (UA * (T_{pre} - T_{post}) * \text{Hours}) / (3412 * RE\_electric)$

Where:

- U

= Overall heat transfer coefficient of tank (BTU/Hr-°F-ft²).

= Actual if known. If unknown assume R-12, U = 0.083
- A

= Surface area of storage tank (square feet)

= Actual if known. If unknown use table below based on capacity of tank. If capacity unknown assume 50 gal tank; A = 24.99 ft²

Capacity (gal)	A (ft²) ⁵⁰⁸
30	19.16
40	23.18
50	24.99
80	31.84

⁵⁰⁷ Note this algorithm provides savings only from reduction in standby losses. VEIC considered avoided energy from not heating the water to the higher temperature but determined that the potential impact for the three major hot water uses was too small to be characterized; Dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings) and clothes washers will only see savings if the water from the tank is taken without any temperature control.

⁵⁰⁸ Assumptions from Pennsylvania TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

- T_{pre}*

= Actual hot water setpoint prior to adjustment.

= 135 degrees default
- T_{post}*

= Actual new hot water setpoint, which may not be lower than 120 degrees

= 120 degrees default
- Hours*

= Number of hours in a year (since savings are assumed to be constant over year).

= 8760
- 3412*

= Conversion from BTU to kWh
- RE_{electric}*

= Recovery efficiency of electric hot water heater

= 0.98⁵⁰⁹

The deemed savings assumption, where site specific assumptions are not available would be as follows:

⁵⁰⁹ Electric water heaters have recovery efficiency of 98%:
<http://www.ahridirectory.org/ahridirectory/pages/home.aspx>

$$\begin{aligned}\Delta \text{kWh} &= (\text{UA} * (\text{Tpre} - \text{Tpost}) * \text{Hours}) / (3412 * \text{RE\_electric}) \\ &= (((0.083 * 24.99) * (135 - 120) * 8760) / (3412 * 0.98)) \\ &= 81.5 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours}$$

Where:

$$\text{Hours} = 8760$$

The deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\begin{aligned}\Delta \text{kW} &= (81.5 / 8760) \\ &= 0.0093 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

For homes with gas water heaters:

$$\Delta \text{MMBTU} = (\text{U} * \text{A} * (\text{Tpre} - \text{Tpost}) * \text{Hours}) / (1,000,000 * \text{RE\_gas})$$

Where

$$1,000,000 = \text{Converts BTUs to MMBTU (BTU/MMBTU)}$$

$$\text{RE\_gas} = \text{Recovery efficiency of gas water heater}$$

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$$= 0.75^{510}$$

The deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\begin{aligned}\Delta\text{MMBTU} &= (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours}) / (1,000,000 * RE_{\text{gas}}) \\ &= (0.083 * 24.99 * (135 - 120) * 8760) / (1,000,000 * 0.75) \\ &= 0.36 \text{ MMBTU}\end{aligned}$$

Annual Water Savings Algorithm

N/A

Incremental Cost

The lifecycle NPV incremental cost of this retrofit measure is assumed to be \$5 for contractor time.

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 2 years.

Operation and Maintenance Impacts

N/A

⁵¹⁰Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

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Appliance End Use

Clothes Washer

Unique Measure Code(s): RS_LA_TOS_CWASHES_0415, RS_LA_TOS_CWASHT2_0415, RS_LA_TOS_CWASHT3_0415, RS_LA_TOS_CWASHME_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding either the ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE Tier 3 minimum qualifying efficiency standards presented below:

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR, CEE Tier 1	>= 2.76	>= 2.06 ⁵¹¹	<= 3.2	<= 4.3 ⁵¹²
CEE TIER 2	>= 2.92	>= 2.92	<= 3.2	<= 3.2
CEE TIER 3	>= 3.10	>= 3.10	<= 3.0	<= 3.0

The Integrated Modified Energy Factor (IMEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry

⁵¹¹ CEE does not distinguish between front loading and top loading, and requires a minimum IMEF of 2.38 in both cases

⁵¹² CEE does not distinguish between front loading and top loading, and requires a maximum IWF of 3.7 in both cases

can be washed and dried with one kWh of electricity 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.

Definition of Baseline Condition

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 is defined in the table below:

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
After Jan 1, 2018	1.84	1.57	4.7	6.5

Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE TIER 3 efficiency criteria presented above.

Annual Energy Savings Algorithm

$$\Delta kWh = [(Capacity * 1/IMEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric\_DHW) + (%Dryerbase * %Electric\_Dryer))] - [(Capacity * 1/IMEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric\_DHW) + (%Dryerbase * %Electric\_Dryer))]$$

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$$1/IMEF_{eff} * N_{cycles}) * (\%C_{weff} + (\%DHW_{eff} * \%Electric\_DHW) + (\%Dryer_{eff} * \%Electric\_Dryer])$$

Where

- Capacity

= Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume average 3.45 cubic feet⁵¹³
- IMEF_{base}

= Integrated Modified Energy Factor of baseline unit
= Values provided in table below
- IMEF_{eff}

= Integrated Modified Energy Factor of efficient unit
= Actual. If unknown assume average values provided below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages ⁵¹⁴	
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading
Federal Standard	>= 1.84	>= 1.57	>= 1.75	67%	33%
ENERGY STAR, CEE Tier 1	>= 2.76	>= 2.06	>= 2.49	62%	38%
CEE TIER 2	>= 2.92	>= 2.92	>= 2.92	98%	2%
CEE TIER 3	>= 3.10	n/a	>= 3.10	100%	0%

Ncycles = Number of Cycles per year

⁵¹³ Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/28/2014.

⁵¹⁴ Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

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	Percentage of Total Energy Consumption ⁵¹⁶		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%
ENERGY STAR, CEE Tier 1	8%	23%	69%
CEE TIER 2	14%	10%	76%
CEE TIER 3	14%	10%	76%

⁵¹⁶ 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) and consumption data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_std_andard.xlsm. See “2015 Clothes Washer Analysis.xls” for the calculation.

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%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	65% ⁵¹⁷

%Electric_Dryer electric = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%
Unknown	79% ⁵¹⁸

The prescriptive kWh savings based on values provided above where DHW and Dryer fuels are unknown is provided below⁵¹⁹:

⁵¹⁷ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

⁵¹⁸ Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

⁵¹⁹ 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.

Efficiency Level	Δ kWH		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	136.3	52.8	104.6
CEE TIER 2	140.6	140.6	140.6
CEE TIER 3	154.6	n/a	154.6

The unit specific kWh savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Dryer/DHW Gas Combo	Δ kWH		
		Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	183.2	75.4	142.2
	Electric Dryer/Gas DHW	101.0	18.0	69.5
	Gas Dryer/Electric DHW	96.9	63.4	84.2
	Gas Dryer/Gas DHW	14.7	6.0	11.4
CEE TIER 2	Electric Dryer/Electric DHW	200.6	200.6	200.6
	Electric Dryer/Gas DHW	75.4	75.4	75.4
	Gas Dryer/Electric DHW	123.3	123.3	123.3
	Gas Dryer/Gas DHW	-2.0	-2.0	-2.0
CEE TIER 3	Electric Dryer/Electric DHW	218.1	n/a	218.1
	Electric Dryer/Gas DHW	91.1	n/a	91.1
	Gas Dryer/Electric DHW	127.4	n/a	127.4
	Gas Dryer/Gas DHW	0.5	n/a	0.5

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Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / \text{Hours} * CF$

- Where:
- Hours = Assumed Run hours of Clothes Washer = 265⁵²⁰
 - CF = Summer Peak Coincidence Factor for measure = 0.029⁵²¹

The prescriptive kW savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	ΔkW		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	0.015	0.006	0.011

⁵²⁰ Metered data from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program.” March 21, 2014, page 36.
⁵²¹ Ibid.

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CEE TIER 2	0.015	0.015	0.015
CEE TIER 3	0.017	n/a	0.017

The unit specific kW savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Dryer/DHW Fuel Combo	ΔkW		
		Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.020	0.008	0.016
	Electric Dryer/Fuel DHW	0.011	0.002	0.008
	Fuel Dryer/Electric DHW	0.011	0.007	0.009
	Fuel Dryer/Fuel DHW	0.002	0.001	0.001
CEE TIER 2	Electric Dryer/Electric DHW	0.022	0.022	0.022
	Electric Dryer/Fuel DHW	0.008	0.008	0.008
	Fuel Dryer/Electric DHW	0.013	0.013	0.013
	Fuel Dryer/Fuel DHW	0.000	0.000	0.000
CEE TIER 3	Electric Dryer/Electric DHW	0.024	n/a	0.024
	Electric Dryer/Fuel DHW	0.010	n/a	0.010
	Fuel Dryer/Electric DHW	0.014	n/a	0.014
	Fuel Dryer/Fuel DHW	0.000	n/a	0.000

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBTU} = [(\text{Capacity} * 1/\text{IMEFbase} * \text{Ncycles}) * ((\% \text{DHWbase} * \% \text{Natural Gas\_DHW} * \text{R\_eff}) + (\% \text{Dryerbase} * \% \text{Gas\_Dryer}))] - [(\text{Capacity} * 1/\text{IMEFeff} * \text{Ncycles}) * ((\% \text{DHWeff} * \% \text{Natural Gas\_DHW} * \text{R\_eff}) + (\% \text{Dryereff} * \% \text{Gas\_Dryer}))] * \text{MMBTU\_convert}$$

Where:

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R_eff = Recovery efficiency factor
= 1.31⁵²²

MMBTU_convert = Conversion factor from kWh to MMBTU
= 0.003413

%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%
Unknown	2435% ⁵²³

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	46% ⁵²⁴

⁵²² To account for the different efficiency of electric and Natural Gas 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 (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore, a factor of 0.98/0.78 (1.26) is applied.

⁵²³ Default assumption for unknown fuel is based on percentage of homes with gas DHW from EIA Residential Energy Consumption Survey (RECS) 202009 for South Mid-Atlantic States_ (5.97m/24.84m total homes).

⁵²⁴ Default assumption for unknown is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 202009 for SouthMid Atlantic States.

Other factors as defined above

The prescriptive MMBTU savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	ΔMMBTU		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	0.15	0.09	0.13
CEE TIER 2	0.21	0.21	0.21
CEE TIER 3	0.22	n/a	0.22

The unit specific MMBTU savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Configuration	ΔMMBTU		
		Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.00	0.00	0.00
	Electric Dryer/Gas DHW	0.37	0.26	0.33
	Gas Dryer/Electric DHW	0.29	0.04	0.20
	Gas Dryer/Gas DHW	0.66	0.30	0.52
CEE TIER 2	Electric Dryer/Electric DHW	0.00	0.00	0.00
	Electric Dryer/Gas DHW	0.56	0.56	0.56
	Gas Dryer/Electric DHW	0.26	0.26	0.26
	Gas Dryer/Gas DHW	0.82	0.82	0.82
CEE TIER 3	Electric Dryer/Electric DHW	0.00	n/a	n/a
	Electric Dryer/Gas DHW	0.57	n/a	n/a
	Gas Dryer/Electric DHW	0.31	n/a	n/a

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Efficiency Level	Configuration	ΔMMBTU		
		Front	Top	Weighted Average
	Gas Dryer/Gas DHW	0.88	n/a	n/a

Annual Water Savings Algorithm
 $\Delta\text{Water (CCF)} = (\text{Capacity} * (\text{IWFbase} - \text{IWFeff})) * \text{Ncycles} / 748$
gallons/CCF

Where

IWFbase = Integrated Water Factor of baseline clothes washer
= Values provided below (gallons/CF of washer capacity)

IWFeff = Integrated Water Factor of efficient clothes washer(gallons/CF of washer capacity)

= Actual. If unknown assume average values provided below.

Efficiency Level	IWF ⁵²⁵		
	Front Loading	Top Loading	Weighted Average
Federal Standard	4.7	6.5	5.29
ENERGY STAR, CEE Tier 1	3.2	4.3	3.56
CEE TIER 2	3.2	3.2	3.2
CEE TIER 3	3.0	3.0	3.0

⁵²⁵ Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

The prescriptive water savings for each efficiency level are presented below:

Efficiency Level	ΔWater (ccf per year)		
	Front Loading	Top Loading	Weighted Average
ENERGY STAR, CEE Tier 1	2.4	1.2	2.0
CEE TIER 2	2.4	2.4	2.4
CEE TIER 3	2.7	2.7	2.7

kWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities’ must be careful not to double count the monetary benefit of these savings within cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

$$\Delta kWh_{water}^{526} = 2.07 \text{ kWh} * \Delta Water \text{ (CCF)}$$

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	ΔkWhwater

⁵²⁶ This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, “Energy Savings Plan, Prepared for DC Water.” Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

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	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	5.1	2.4	4.1
CEE TIER 2	5.1	5.1	5.1
CEE TIER 3	5.6	5.6	5.6

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided in the table below:⁵²⁷

Purchase Date	Efficiency Level	Front Loading	Top Loading
After Jan 1, 2018	ENERGY STAR, CEE Tier 1	\$17	\$21
	CEE TIER 2	\$28	\$50
	CEE TIER 3	\$34	NA

Measure Life

The measure life is assumed to be 14 years⁵²⁸.

⁵²⁷ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

⁵²⁸ Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm

Operation and Maintenance Impacts
n/a

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Clothes Washer, Early Replacement

Unique Measure Code(s): RS_LA_EREP_CWASHES_0415, RS_LA_EREP_CWASHT2_0415, RS_LA_EREP_CWASHT3_0415, RS_LA_EREP_CWASHME_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the early removal of an existing inefficient clothes washer from service, prior to its natural end of life, and replacement with a new unit exceeding either the ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE Tier 3 minimum qualifying efficiency standards presented below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading (≥ 2.5 cu-ft)	Top Loading (≥ 2.5 cu-ft)	Front Loading	Top Loading
ENERGY STAR, CEE Tier 1	≥ 2.76	≥ 2.06 ⁵²⁹	≤ 3.2	≤ 4.3 ⁵³⁰
CEE TIER 2	≥ 2.92	≥ 2.92	≤ 3.2	≤ 3.2
CEE TIER 3	≥ 3.10	≥ 3.10	≤ 3.0	≤ 3.0

The Integrated modified energy factor (MEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry

⁵²⁹ CEE does not distinguish between front loading and top loading, and requires a minimum IMEF of 2.38 in both cases
⁵³⁰ CEE does not distinguish between front loading and top loading, and requires a maximum IWF of 3.7 in both cases

can be washed and dried with one kWh of electricity 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.

Savings are calculated between the existing unit and the new efficient unit consumption during the assumed remaining life of the existing unit, and between a hypothetical new baseline unit and the efficient unit consumption for the remainder of the measure life.

Definition of Baseline Condition

The baseline condition is the existing inefficient clothes washer for the remaining assumed useful life of the unit, assumed to be 5 years⁵³¹, and then for the remainder of the measure life (next 9 years) the baseline becomes a new replacement unit meeting the minimum federal efficiency standard presented above.

The existing unit efficiency is assumed to be 1.0 IMEF for front loaders and 0.84 IMEF for top loaders. This is based on the Federal Standard for clothes washers from 2004 - 2015; 1.26 MEF converted to IMEF using an ENERGY STAR conversion tool copied in to the reference calculation spreadsheet "2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls". The Integrated Water Factor is assumed to be 8.2 IWF for front loaders and 8.4 for top loaders, based on a similar conversion of the 2004 Federal Standard 7.93 WF.

The new baseline unit is consistent with the Time of Sale measure.

The baseline assumptions are provided below:

⁵³¹ Based on 1/3 of the measure life.

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
Existing unit	1.0	0.84	8.2	8.4
Federal Standard after Jan 1, 2018	1.84	1.57	4.7	6.5

Definition of Efficient Condition
The efficient condition is a clothes washer meeting either the ENERGY STAR/ CEE Tier 1, CEE Tier 2 or CEE Tier 3 efficiency criteria presented above.

Annual Energy Savings Algorithm
(see ‘2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls’ for detailed calculation)

$$\Delta kWh = [(Capacity * 1/IMEFbase * Ncycles) * (%CWbase + (%DHWbase * \%Electric\_DHW) + (\%Dryerbase * \%Electric\_Dryer))] - [(Capacity * 1/IMEFeff * Ncycles) * (%CWeff + (\%DHWeff * \%Electric\_DHW) + (\%Dryereff * \%Electric\_Dryer))]$$

Where
Capacity = Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume average 3.45 cubic feet⁵³²

⁵³² Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/28/2014.

IMEF_{base} = Integrated Modified Energy Factor of baseline unit
 = Values provided in table below
IMEF_{eff} = Integrated Modified Energy Factor of efficient unit
 = Actual. If unknown assume average values provided below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages ⁵³³	
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading
Existing Unit ⁵³⁴	1.0	0.84	n/a ⁵³⁵	n/a	n/a
Federal Standard	>= 1.84	>= 1.57	>= 1.75	67%	33%
ENERGY STAR, CEE Tier 1	>= 2.76	>= 2.06	>= 2.49	62%	38%
CEE TIER 2	>= 2.92	>= 2.92	>= 2.92	98%	2%
CEE TIER 3	>= 3.10	n/a	>= 3.10	100%	0%

N_{cycles} = Number of Cycles per year
 = 254⁵³⁶
%CW = Percentage of total energy consumption for Clothes Washer operation
%DHW = Percentage of total energy consumption used for water heating

⁵³³ Weighting percentages are based on available product from the CEC database.

⁵³⁴ Existing units efficiencies are based upon an MEF of 1.26 , the 2004 Federal Standard, converted to IMEF using an ENERGY STAR conversion tool.

⁵³⁵ For early replacement measures we will always know the configuration of the replaced machine.

⁵³⁶ Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

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%Dryer = Percentage of total energy consumption for dryer operation
(dependent on efficiency level – see table below)

	Percentage of Total Energy Consumption ⁵³⁷		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%
ENERGY STAR, CEE Tier 1	8%	23%	69%
CEE TIER 2	14%	10%	76%
CEE TIER 3	14%	10%	77%

%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%

%Electric_Dryer = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%

⁵³⁷ 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) and consumption data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.

Fossil Fuel 0%

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Efficiency Level	Dryer/DHW Fuel Combo	Remaining life of existing unit (first 5 years) ΔkWH		Remaining measure life (next 9 years) ΔkWH	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top	Weighted Average	Front	Top	Front	Top
ENERGY STAR, CEE TIER 1	Electric Dryer/Electric DHW	558.8	617.8	110.8	20%	18%	270.8	291.9
	Electric Dryer/Gas DHW	360.2	392.3	45.3	13%	12%	157.7	169.2
	Gas Dryer/Electric DHW	243.3	275.0	74.4	31%	27%	134.7	146.0
	Gas Dryer/Gas DHW	44.7	49.4	8.9	20%	18%	21.7	23.4
CEE TIER 2	Electric Dryer/Electric DHW	576.2	743.1	181.3	31%	24%	322.3	382.0
	Electric Dryer/Gas DHW	334.6	449.7	58.0	17%	13%	156.8	197.9
	Gas Dryer/Electric DHW	269.7	334.8	118.6	44%	35%	172.6	195.8
	Gas Dryer/Gas DHW	28.1	41.4	-4.7	-17%	-11%	7.0	11.8
CEE TIER 3	Electric Dryer/Electric DHW	593.6	n/a	200.6	34%	n/a	341.0	n/a
	Electric Dryer/Gas DHW	350.2	n/a	75.4	22%	n/a	173.6	n/a
	Gas Dryer/Electric DHW	273.9	n/a	123.3	45%	n/a	177.1	n/a
	Gas Dryer/Gas DHW	30.5	n/a	-2.0	-6%	n/a	9.6	n/a

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/Hours * CF

Where:

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Hours = Assumed Run hours of Clothes Washer
 = 265⁵³⁸
CF = Summer Peak Coincidence Factor for measure
 = 0.029⁵³⁹

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Efficiency Level	Dryer/DHW Fuel Combo	Remaining life of existing unit (first 5 years) ΔkW		Remaining measure life (next 9 years) ΔkW Weighted Average	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top		Front	Top	Front	Top
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.061	0.068	0.012	20%	18%	0.030	0.032
	Electric Dryer/Fuel DHW	0.039	0.043	0.005	13%	12%	0.017	0.019
	Fuel Dryer/Electric DHW	0.027	0.030	0.008	31%	27%	0.015	0.016
	Fuel Dryer/Fuel DHW	0.005	0.005	0.001	20%	18%	0.002	0.003
CEE TIER 2	Electric Dryer/Electric DHW	0.063	0.081	0.020	31%	24%	0.035	0.042
	Electric Dryer/Fuel DHW	0.037	0.049	0.006	17%	13%	0.017	0.022
	Fuel Dryer/Electric DHW	0.030	0.037	0.013	44%	35%	0.019	0.021
	Fuel Dryer/Fuel DHW	0.003	0.005	-0.001	-17%	-11%	0.001	0.001
CEE TIER 3	Electric Dryer/Electric DHW	0.065	n/a	0.022	34%	n/a	0.037	n/a

⁵³⁸ Metered data from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program.” March 21, 2014, page 36.

⁵³⁹ Ibid.

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Electric Dryer/Fuel DHW	0.038	n/a	0.008	22%	n/a	0.019	n/a
Fuel Dryer/Electric DHW	0.030	n/a	0.013	45%	n/a	0.019	n/a
Fuel Dryer/Fuel DHW	0.003	n/a	0.000	-6%	n/a	0.001	n/a

Annual Fossil Fuel Savings Algorithm

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas DHW and Natural Gas dryer savings from total savings:

$$\Delta \text{MMBTU} = [(\text{Capacity} * 1/\text{IMEFbase} * \text{Ncycles}) * ((\% \text{DHWbase} * \% \text{Natural Gas\_DHW} * R_{\text{eff}}) + (\% \text{Dryerbase} * \% \text{Gas\_Dryer}))] - [(\text{Capacity} * 1/\text{IMEFeff} * \text{Ncycles}) * ((\% \text{DHWeff} * \% \text{Natural Gas\_DHW} * R_{\text{eff}}) + (\% \text{Dryereff} * \% \text{Gas\_Dryer}))] * \text{MMBTU\_convert}$$

Where:

R_{eff} = Recovery efficiency factor
= 1.26⁵⁴⁰

MMBTU_convert = Conversion factor from kWh to MMBTU
= 0.003413

$\% \text{Natural Gas\_DHW}$ = Percentage of DHW savings assumed to be Natural Gas

⁵⁴⁰ 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 (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore a factor of 0.98/0.78 (1.26) is applied.

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DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%

Other factors as defined above

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Efficiency Level	Configuration	Remaining life of existing unit (first 5 years) ΔMMBTU		Remaining measure life (next 9 years) ΔMMBTU	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top	Weighted Average	Front	Top	Front	Top
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.00	0.00	0.00	n/a	n/a	0.00	0.00
	Electric Dryer/Gas DHW	0.85	0.97	0.28	0.33	0.29	0.49	0.53
	Gas Dryer/Electric DHW	1.08	1.17	0.12	0.12	0.11	0.46	0.50
	Gas Dryer/Gas DHW	1.93	2.14	0.41	0.21	0.19	0.95	1.03
CEE TIER 2	Electric Dryer/Electric DHW	0.00	0.00	0.00	n/a	n/a	0.00	0.00

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CEE TIER 3	Electric Dryer/Gas DHW	1.04	1.26	0.53	0.51	0.42	0.71	0.79
	Gas Dryer/Electric DHW	1.05	1.39	0.21	0.20	0.15	0.51	0.64
	Gas Dryer/Gas DHW	2.09	2.66	0.74	0.36	0.28	1.22	1.43
	Electric Dryer/Electric DHW	0.00	n/a	0.00	n/a	n/a	0.00	n/a
	Electric Dryer/Gas DHW	1.05	n/a	0.54	n/a	n/a	0.72	n/a
	Gas Dryer/Electric DHW	1.09	n/a	0.26	n/a	n/a	0.56	n/a
	Gas Dryer/Gas DHW	2.14	n/a	0.80	n/a	n/a	1.28	n/a

Annual Water Savings Algorithm

$$\Delta \text{Water (CCF)} = (\text{Capacity} * (\text{IWFbase} - \text{IWFeff})) * \text{Ncycles} / 748$$

gallons / CCF

Where

- WFbase* = Integrated Water Factor of baseline clothes washer
= Values provided below
- WFeff* = Integrated Water Factor of efficient clothes washer
= Actual. If unknown assume average values provided below.

Efficiency Level	IWF ⁵⁴¹		
	Front Loading	Top Loading	Weighted Average

⁵⁴¹ Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database.

Existing ⁵⁴²	8.2	8.4	n/a ⁵⁴³
Federal Standard	4.7	6.5	5.29
ENERGY STAR, CEE Tier 1	3.2	4.3	3.56
CEE TIER 2	3.2	3.2	3.2
CEE TIER 3	3.0	3.0	3.0

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below⁵⁴⁴:

Efficiency Level	Remaining life of existing unit (first 5 years) ΔWater (ccf per year)		Remaining measure life (next 9 years) ΔWater (ccf per year)	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
	Front	Top	Weighted Average	Front	Top	Front	Top
Existing	n/a	n/a	n/a	n/a	n/a	n/a	n/a

⁵⁴² Existing units efficiencies are based upon an WF of 7.93 which was the previous new baseline assumption - converted to IWF using an ENERGY STAR conversion tool copied in to the "2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls" worksheet.

⁵⁴³ For early replacement measures we will always know the configuration of the replaced machine.

⁵⁴⁴ Water Factor is the number of gallons required for each cubic foot of laundry. For ENERGY STAR and CEE Tiers 2 and 3 the average WF of units in the following evaluation are used; Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36. For baseline and ENERGY STAR Most Efficient the average WF of the post 1/1/2011 units available in each classification is used (based on data pulled from the California Energy Commission Appliance Efficiency Database <http://www.appliances.energy.ca.gov/>)

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Federal Standard	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ENERGY STAR, CEE Tier 1	5.9	4.8	2.0	33%	41%	3.4	3.0
CEE TIER 2	5.9	6.1	2.4	42%	40%	3.7	3.7
CEE TIER 3	6.1	n/a	2.7	44%	n/a	3.9	n/a

kWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities' must be careful not to double count the monetary benefit of these savings within cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

$$\Delta \text{kWh}_{\text{water}}^{545} = 2.07 \text{ kWh} * \Delta \text{Water (CCF)}$$

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	Remaining life of existing unit (first 5 years) ΔWater (ccf per year)	Remaining measure life (next 9 years) ΔWater (ccf per year)	Mid Life Adjustment	Equivalent Weighted Average Annual Savings

⁵⁴⁵ This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

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	Front	Top	Weighted Average	Front	Top	Front	Top
Existing	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Federal Standard	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ENERGY STAR, CEE Tier 1	12.1	9.9	4.1	33%	41%	6.9	6.2
CEE TIER 2	12.1	12.6	5.1	42%	40%	7.6	7.8
CEE TIER 3	12.6	n/a	5.6	44%	n/a	8.1	n/a

Incremental Cost

The lifecycle NPV incremental cost for this early replacement measure is provided in the table below:⁵⁴⁶

Purchase Date	Efficiency Level	Front Loading	Top Loading
After Jan 1, 2018	ENERGY STAR, CEE Tier 1	\$444	\$354
	CEE TIER 2	\$455	\$455
	CEE TIER 3	\$427	NA

Measure Life

⁵⁴⁶ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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The measure life is assumed to be 14 years⁵⁴⁷ and the existing unit is assumed to have a remaining life of 5 years⁵⁴⁸.

Operation and Maintenance Impacts

n/a

⁵⁴⁷ Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm

⁵⁴⁸ Based on 1/3 of the measure life.

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Dehumidifier

Unique Measure Code(s): RS_AP_TOS_DEHUMID_0619
Effective Date: June 2019
End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR (Version ~~4.05~~)⁵⁴⁹ in place of a unit that meets the minimum federal standard efficiency.

Definition of Baseline Condition

The baseline for this measure is defined as a new dehumidifier that meets the Federal Standard efficiency standards as defined below:

Capacity (pints/day)	Federal Standard Criteria before 6/13/2019 (L/kWh) ⁵⁵⁰
Up to 35	≥1.35
> 35 to ≤45	≥1.50
> 45 to ≤ 54	≥1.60

⁵⁴⁹ Energy Star Version ~~5.04.0~~ became effective 10/~~25/46~~31/19
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements_0.pdf

⁵⁵⁰ The Federal Standard for Dehumidifiers changed as of October 2012;
<https://www.federalregister.gov/articles/2010/12/02/2010-29756/energy-conservation-program-for-consumer-products-test-procedures-for-residential-dishwashers#h-11>

> 54 to ≤ 75	≥1.70
> 75 to ≤ 185	≥2.50

Capacity (pints/day)	Federal Standard Criteria after 6/13/2019 (L/kWh) ⁵⁵¹
Up to 25	≥1.30
> 25 to ≤50	≥1.60
> 50.01	≥2.80

Definition of Efficient Condition

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards version 4.05.0 effective 10/25/2019⁵⁵² as defined below:

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
<75	≥2.00
75 to ≤185	≥2.80

Capacity	ENERGY STAR Criteria after 10/31/19

⁵⁵¹ The Federal Standard for Dehumidifiers changed as of October 2012;
<https://www.federalregister.gov/articles/2010/12/02/2010-29756/energy-conservation-program-for-consumer-products-test-procedures-for-residential-dishwashers#h-11>
⁵⁵² https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Dehumidifiers%20Version%205.0%20Program%20Requirements_0.pdfhttps://www.energystar.gov/products/spec/dehumidifiers_specification_version_4_0_pdf

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(pints/day) Range	(≥ L/kWh)
≤25	1.57
> 25 to ≤50	1.8
> 50 to ≤75	3.3
75 to ≤185	3.3

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = \text{Capacity} * 0.473 / 24 * \text{Hours} * (1 / (\text{L/kWh}_{\text{Base}}) - 1 / (\text{L/kWh}_{\text{Eff}}))$$

Where:

Capacity = Capacity of the unit (pints/day)
0.473 = Constant to convert Pints to Liters
24 = Constant to convert Liters/day to Liters/hour
Hours = Run hours per year
= 1632⁵⁵³
L/kWh = Liters of water per kWh consumed, as provided in tables above

⁵⁵³ Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator
http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

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Annual kWh results for each capacity class are presented below using the average of the capacity range. If the capacity of installed units is collected, the savings should be calculated using the algorithm. If the capacity is unknown, a default average value is provided:

				Annual kWh		
Capacity	Capacity Used	Federal Standard Criteria	ENERGY STAR Criteria	Federal Standard	ENERGY STAR	Savings
(pints/day) Range		(≥ L/kWh)	(≥ L/kWh)			
≤25	20	1.35	2.0	477	322	155
> 25 to ≤35	30	1.35	2.0	715	482	232
> 35 to ≤45	40	1.5	2.0	858	643	214
> 45 to ≤ 54	50	1.6	2.0	1005	804	201
> 54 to ≤ 75	65	1.7	2.0	1230	1045	184
> 75 to ≤ 185	130	2.5	2.8	1673	1493	179
Average	56	1.7	2.1	993	798	194

Annual kWh

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Capacity	Capacity Used	Federal Standard Criteri after 6/19	ENERGY STAR Criteria after 10/31/19	Federal Standard post June 2019	ENERGY STAR	Savings
(pints/day) Range		(≥ L/kWh)	(≥ L/kWh)			
≤25	20	1.3	1.57	495	410	85
> 25 to ≤50	37	1.6	1.8	744	661	83
> 50 to ≤75	62	2.8	3.3	712	604	108
75 to ≤185	130	2.8	3.3	1,493	1,267	226

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / \text{Hours} * CF$

Where:

Hours = Annual operating hours

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CF = 1632 hours⁵⁵⁴
= Summer Peak Coincidence Factor for measure
= 0.37⁵⁵⁵

Before 10/31/19:

Capacity	ΔkW
(pints/day) Range	
≤25	0.039
> 25 to ≤35	0.053
> 35 to ≤45	0.049
> 45 to ≤ 54	0.046
> 54 to ≤ 75	0.042
> 75 to ≤ 185	0.041
Average	0.044

After 10/31/19:

⁵⁵⁴ Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

⁵⁵⁵ Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

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Capacity (pints/day) Range	ΔkW
≤ 25	0.0193
> 25 to ≤ 50	0.0187
> 50 to ≤ 75	0.0245
75 to ≤ 155	0.0513

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$5⁵⁵⁶.

Measure Life

The measure life is assumed to be 12 years.⁵⁵⁷

⁵⁵⁶ Based on available data from the Department of Energy's Life Cycle Cost analysis spreadsheet:

http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_dehumidifier.xls

⁵⁵⁷ ENERGY STAR Dehumidifier Calculator

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

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Operation and Maintenance Impacts
n/a

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Dehumidifier, Early Retirement / Recycling

Unique Measure Code(s): RS_AP_ERET_DEHUMID_0619
Effective Date: June 2019
End Date: TBD

Measure Description

This measure describes the savings resulting from removing an existing, operating dehumidifier from service prior to its natural end of life. ~~The program should target, but not be limited to, dehumidifiers put into service prior to June 2019.~~ If primary data indicate the unit is replaced rather than retired, savings should be based on the Dehumidifier Time-of-Sale measure.

Definition of Baseline Condition

The baseline condition is the existing inefficient dehumidifier.

Definition of Efficient Condition

The existing inefficient dehumidifier is removed from service and not replaced.

Energy Savings Algorithm

Remaining life kWh savings =

$$Capacity \times \frac{.473}{24} \times hours \times \frac{1}{L \text{ per kWh}} \times (Service \text{ Life} - Existing \text{ Age})$$

Where:

- Capacity = Capacity of the unit (pints/day)
- 0.473 = Constant to convert Pints to Liters
- 24 = Constant to convert Liters/day to Liters/hour
- Hours = Run hours per year

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L/kWh = 1632⁵⁵⁸
= *Liters of water per kWh consumed, as provided in table below. Values reflect a manufacture date range that coincides with timing of federal efficiency standards.*

Service Life = 12
Existing Age = *age of existing unit*

Annual kWh savings results for each capacity class are presented in the table below reflecting two recent federal standards as baseline. If the capacity of installed units is collected, the savings should be calculated using the algorithm. If the capacity is unknown, a default average value is provided. If the unit being removed is Energy Star labeled, custom calculation will be required.

				Annual kWh Savings	
Capacity (pints/day) Range	Capacity of existing unit	2007 Federal Standard (≥ L/kWh) ⁵⁵⁹	2012 Federal Standard (≥ L/kWh) ⁵⁶⁰	Mfr date before Oct 2012	Mfr date between Nov 2012 and June 2019
≤25	20	1	1.35	643	477
> 25 to ≤35	30	1.2	1.35	804	715

⁵⁵⁸ Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

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> 35 to ≤45	40	1.3	1.5	990	858
> 45 to ≤ 54	50	1.3	1.6	1237	1005
> 54 to ≤ 75	65	1.5	1.7	1394	1230
> 75 to ≤ 185	130	2.25	2.5	1858	1673
Average	56	1.43	1.67	1260	1077

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \frac{\Delta kWh}{Hours} \times CF$$

Where:

- kWh

Hours

CF
- = annual kWh savings

= Annual operating hours

= 1632 hours⁵⁶¹

= Summer Peak Coincidence Factor for measure

= 0.37⁵⁶²

⁵⁶¹ Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

⁵⁶² Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

Capacity (pints/day) Range	Δ kW before 2012	Δ kW 2012- 2019
≤ 25	0.146	0.108
> 25 to ≤ 35	0.182	0.162
> 35 to ≤ 45	0.224	0.194
> 45 to ≤ 54	0.280	0.228
> 54 to ≤ 75	0.316	0.279
> 75 to ≤ 185	0.421	0.379
Average	0.262	0.225

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
n/a

Measure Life
n/a

Operation and Maintenance Impacts
n/a

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ENERGY STAR Air Purifier/Cleaner

Unique Measure Code(s): RS_AP_TOS_AIRPUR_0414
Effective Date: June 2014
End Date: TBD

Measure Description

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of a baseline model.

Definition of Baseline Condition

The baseline equipment is assumed to be a conventional non-ENERGY STAR unit with consumption estimates based upon EPA research on available models, 2011⁵⁶³.

Definition of Efficient Condition

The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR [V2.0](#)⁵⁶⁴ as provided below.

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust⁵⁶⁵ to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)

⁵⁶³ ENERGY STAR Appliance Savings Calculator;
<https://dnr.mo.gov/sites/dnr/files/media/file/2021/01/energy-star-appliance-calculator.xlsx>http://www.energystar.gov/buildings/sites/default/uploads/files/appliance-calculator.xlsx?7224-046c-87224-046ceiling_fan_calculator.xlsx-8a0f2-2e6f8a0f2-2e6f
⁵⁶⁴ https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%202.0%20Room%20Air%20Cleaners%20Specification%20%28Rev.%20May%202022%29_0.pdf
⁵⁶⁵ Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard

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- Standby Power Requirement: = 2.0 Watts Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{Base} - kWh_{ESTAR}$

Where:

- kWh_{BASE}

= Baseline kWh consumption per year⁵⁶⁶

= see table below
- kWh_{ESTAR}

= ENERGY STAR kWh consumption per year⁵⁶⁷

⁵⁶⁶ Based on assumptions found in the ENERGY STAR Appliance Savings Calculator; Efficiency 1.0 CADR/Watt, 16 hours a day, 365 days a year and 1W standby power.

⁵⁶⁷ Ibid.

Efficiency 3.0 CADR/Watt, 16 hours a day, 365 days a year and 0.6W standby power.

= see table below

Clean Air Delivery Rate (CADR)	CADR used in calculation	Baseline Unit Energy Consumption (kWh/year)	ENERGY STAR Unit Energy Consumption (kWh/year)	ΔkWh
CADR 51-100	75	441	148	293
CADR 101-150	125	733	245	488
CADR 151-200	175	1025	342	683
CADR 201-250	225	1317	440	877
CADR Over 250	275	1609	537	1072

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / \text{Hours} * CF$

Where:

- ΔkWh = Gross customer annual kWh savings for the measure
- Hours = Average hours of use per year
 - = 5840 hours⁵⁶⁸
- CF = Summer Peak Coincidence Factor for measure

⁵⁶⁸ Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

= 0.67⁵⁶⁹

Clean Air Delivery Rate	ΔkW
CADR 51-100	0.034
CADR 101-150	0.056
CADR 151-200	0.078
CADR 201-250	0.101
CADR Over 250	0.123

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$0.⁵⁷⁰

Measure Life

The measure life is assumed to be 9 years⁵⁷¹.

Operation and Maintenance Impacts

⁵⁶⁹ Assumes appliance use is equally likely at any hour of the day or night.

⁵⁷⁰ ENERGY STAR Appliance Savings Calculator, which cites “EPA research on available models, 2012”

⁵⁷¹ ENERGY STAR Appliance Savings Calculator; Based on Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

There are no operation and maintenance cost adjustments for this measure.⁵⁷²

⁵⁷² Some types of room air cleaners require filter replacement or periodic cleaning, but this is likely to be true for both efficient and baseline units and so no difference in cost is assumed.

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Clothes Dryer

Unique Measure Code(s): RS_AP_TOS_CLTDRY_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR criteria. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers⁵⁷³. ENERGY STAR provides criteria for both gas and electric clothes dryers.

Definition of Baseline Condition

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

Definition of Efficient Condition

⁵⁷³ ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011.
http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

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Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

Annual Energy Savings Algorithm

$\Delta kWh = (Load/CEF_{base} - Load/CEF_{eff}) * N_{cycles} * \%Electric$

Where:

Load = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

Dryer Size	Load (lbs.) ⁵⁷⁴
Standard	8.45
Compact	3

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis⁵⁷⁵. If product class unknown, assume electric, standard.

Product Class	CEFbase (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft ³)	3.11
Vented Electric, Compact (120V) (< 4.4 ft ³)	3.01
Vented Electric, Compact (240V) (<4.4 ft ³)	2.73
Ventless Electric, Compact (240V) (<4.4 ft ³)	2.13

⁵⁷⁴ Based on ENERGY STAR test procedures.
https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

⁵⁷⁵ ENERGY STAR Draft 2-Version 1.0-1 Clothes Dryers Data and Analysis

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Product Class	CEFbase (lbs/kWh)
Vented Gas	2.84 ⁵⁷⁶

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.⁵⁷⁷ If product class unknown, assume electric, standard.

Product Class	CEFeff (lbs/kWh)
Vented or Ventless Electric, Standard (≥ 4.4 ft ³)	3.93
Vented or Ventless Electric, Compact (120V) (< 4.4 ft ³)	3.80
Vented Electric, Compact (240V) (< 4.4 ft ³)	3.45
Ventless Electric, Compact (240V) (< 4.4 ft ³)	2.68
Vented Gas	3.48 ⁵⁷⁸

Ncycles = Number of dryer cycles per year
= 311 cycles per year.⁵⁷⁹
%Electric = The percent of overall savings coming from electricity

⁵⁷⁶ Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

⁵⁷⁷ ENERGY STAR Clothes Dryers Key Product Criteria.
https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%201.1%20Clothes%20Dryers%20Specification%20-%20Program%20Commitment%20Criteria%20and%20Eligibility%20Criteria_0.pdfhttps://www.energystar.gov/index.cfm?c=clothesdryer_crit_clothes_dryers

⁵⁷⁸ Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

⁵⁷⁹ Ecova, ‘Dryer Field Study’, Northwest Energy Efficiency Alliance (NEEA) 2014.

Clothes Dryer Fuel Type	%Electric ⁵⁸⁰
Electric	100%
Gas	16%

Product Class	Algorithm	ΔkWh
Vented or Ventless Electric, Standard (≥ 4.4 ft³)	= ((8.45/3.11 – 8.45/3.93) * 311 * 100%)	176.3
Vented or Ventless Electric, Compact (120V) (< 4.4 ft³)	= ((3/3.01 – 3/3.80) * 311 * 100%)	64.4
Vented Electric, Compact (240V) (< 4.4 ft³)	= ((3/2.73 – 3/3.45) * 311 * 100%)	71.3
Ventless Electric, Compact (240V) (< 4.4 ft³)	= ((3/2.13 – 3/2.68) * 311 * 100%)	89.9
Vented Gas	= ((8.45/2.84 – 8.45/3.48) * 311 * 16%)	27.2

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / \text{Hours} * CF$

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer.
=290 hours per year.⁵⁸¹

CF = Summer Peak Coincidence Factor for measure

⁵⁸⁰ %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 16% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

⁵⁸¹ Assumes average of 56 minutes per cycle based on Ecova, ‘Dryer Field Study’, Northwest Energy Efficiency Alliance (NEEA) 2014

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$= 2.9\%^{582}$

Product Class	Algorithm	ΔkW
Vented or Ventless Electric, Standard (≥ 4.4 ft ³)	= 176.3/290 * 0.029	0.018
Vented or Ventless Electric, Compact (120V) (< 4.4 ft ³)	= 64.4/290 * 0.029	0.006
Vented Electric, Compact (240V) (< 4.4 ft ³)	= 71.3/290 * 0.029	0.007
Ventless Electric, Compact (240V) (< 4.4 ft ³)	= 89.9/290 * 0.029	0.009
Vented Gas	= 27.2/290 * 0.029	0.003

Annual Fossil Fuel Savings Algorithm

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

$$\begin{aligned} \Delta \text{MMBTU} &= (\text{Load}/\text{CEF}_{\text{base}} - \text{Load}/\text{CEF}_{\text{eff}}) * \text{Ncycles} * \text{MMBTU}_{\text{convert}} * \\ \% \text{Gas} \end{aligned}$$

Where:

$$\begin{aligned} \text{MMBTU}_{\text{convert}} &= \text{Conversion factor from kWh to MMBTU} \\ &= 0.003413 \end{aligned}$$

$$\% \text{Gas} = \text{Percent of overall savings coming from gas}$$

⁵⁸² Consistent with coincidence factor of Clothes Washers; Metered data from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program.” March 21, 2014, page 36.

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Clothes Dryer Fuel Type	%Gas ⁵⁸³
Electric	0%
Gas	84%

Product Class	Algorithm	ΔMMBTU
Vented or Ventless Electric, Standard (≥ 4.4 ft ³)	n/a	0
Vented or Ventless Electric, Compact (120V) (< 4.4 ft ³)	n/a	0
Vented Electric, Compact (240V) (< 4.4 ft ³)	n/a	0
Ventless Electric, Compact (240V) (< 4.4 ft ³)	n/a	0
Vented Gas	$= (8.45/2.84 - 8.45/3.48) * 311 * 0.003413 * 0.84$	0.49

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental cost for a time of sale ENERGY STAR clothes dryer is assumed to be \$75.⁵⁸⁴

Measure Life

⁵⁸³ %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.
⁵⁸⁴ Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”

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The expected measure life is assumed to be 14 years⁵⁸⁵.

Operation and Maintenance Impacts

n/a

⁵⁸⁵ Based on an average estimated range of 12-16 years. ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. November 2011.
http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

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Dishwasher

Unique Measure Code(s): RS_AP_TOS_DISHWAS_0415
Effective Date: June 2015
End Date: TBD

Measure Description

A dishwasher meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard. This measure is only for standard dishwashers, not compact dishwashers. A compact dishwasher is a unit that holds less than eight place settings with six serving pieces.

Definition of Baseline Condition

The baseline for this measure is defined as a new dishwasher that meets the Federal Standard efficiency standards as defined below⁵⁸⁶:

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard	307	5.0

Definition of Efficient Condition

To qualify for this measure, the new dishwasher must meet the ENERGY STAR standards version 6.0 as defined below:

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle

⁵⁸⁶ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

Standard	270	3.50

Annual Energy Savings Algorithm

$$\Delta kWh^{587} = ((kWh_{BASE} - kWh_{ESTAR}) * (\%kWh_{op} + (\%kWh_{heat} * \%Electric\_DHW))))$$

Where:

- kWh_{BASE}*

= Baseline kWh consumption per year

= 307 kWh
- kWh_{ESTAR}*

= ENERGY STAR kWh annual consumption = 270
- %kWh_{op}*

= Percentage of dishwasher energy consumption used for unit operation

= 1 - 56%⁵⁸⁸

= 44%
- %kWh_{heat}*

= Percentage of dishwasher energy consumption used for water heating

= 56%⁵⁸⁹
- %Electric_{DHW}*

= Percentage of DHW savings assumed to be electric

⁵⁸⁷ The Federal Standard and ENERGY STAR annual consumption values include electric consumption for both the operation of the machine and for heating the water that is used by the machine.

⁵⁸⁸ ENERGY STAR Dishwasher Calculator, see ‘EnergyStarCalculatorConsumerDishwasher.xls’.

⁵⁸⁹ Ibid.

DHW fuel	%Electric_DHW
Electric	100%
Natural Gas	0%
Unknown	65% ⁵⁹⁰

DHW Fuel	Algorithm	ΔkWh
Electric	= ((307 - 270) * (0.44 + (0.56 * 1.0)))	37
Unknown	= ((307 - 270) * (0.44 + (0.56 * 0.65)))	29.7

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / \text{Hours} * CF$

Where:

$\text{Hours} = \text{Annual operating hours}^{591}$
 $= 210 \text{ hours}$

⁵⁹⁰ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the Mid-Atlantic region.

⁵⁹¹ Assuming one and a half hours per cycle and 140 cycles per year therefore 210 operating hours per year; 140 cycles per year is based on a weighted average of dishwasher usage in Mid-Atlantic region derived from the 2009 RECs data;
<http://205.254.135.7/consumption/residential/data/2009/>

CF = Summer Peak Coincidence Factor
= 2.6%⁵⁹²

DHW Fuel	Algorithm	ΔkW
Electric	= 37/210 * 0.026	0.0046
Unknown	= 29.75/210 * 0.02	0.0037

Annual Fossil Fuel Savings Algorithm

$$\Delta\text{MMBTU} = (\text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}) * \% \text{kWh}_{\text{heat}} * \% \text{Natural Gas}_{\text{DHW}} * R_{\text{eff}} * 0.003413$$

Where

%kWh_{heat} = % of dishwasher energy used for water heating
= 56%
%Natural Gas_{DHW} = Percentage of DHW savings assumed to be Natural Gas

⁵⁹² Based on 8760 end use data for Missouri, provided to VEIC by Ameren for use in the Illinois TRM. The average DW load during peak hours is divided by the peak load. In the absence of a Mid Atlantic specific loadshape this is deemed a reasonable proxy since loads would likely be similar.

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%
Unknown	35% ⁵⁹³

R_{eff} = Recovery efficiency factor

= 1.31⁵⁹⁴

0.003413 = factor to convert from kWh to MMBTU

ENERGY STAR Specification	DHW Fuel	Algorithm	ΔMMBTU
6.0	Gas	$= (307 - 270) * 0.56 * 1.0 * 1.31 * 0.003413$	0.09
6.0	Unknown	$= (307 - 270) * 0.56 * 0.35 * 1.31 * 0.003413$	0.03

⁵⁹³ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the states of Delaware, Maryland, West Virginia and the District of Columbia. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

⁵⁹⁴ To account for the different efficiency of electric and Natural Gas water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.75 used to account for older existing units)), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore, a factor of 0.98/0.75 (1.31) is applied.

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Annual Water Savings Algorithm

$\Delta CCF = (Water_{Base} - Water_{EFF}) * GalToCCF$

Where

$Water_{Base}$ = annual water consumption of conventional unit
= 700 gallons⁵⁹⁵

$Water_{EFF}$ = annual water consumption of efficient unit:

ENERGY STAR Specification	WaterEFF (gallons)
6.0	490 ⁵⁹⁶

$GalToCCF$ = factor to convert from gallons to CCF
= 0.001336

ENERGY STAR Specification	Algorithm	ΔCCF

⁵⁹⁵ Assuming 5 gallons/cycle (maximum allowed) and 140 cycles per year based on a weighted average of dishwasher usage in the Mid-Atlantic Region derived from the 2009 RECs data; <http://205.254.135.7/consumption/residential/data/2009/>

⁵⁹⁶ Assuming 3.50 gallons/cycle (maximum allowed) and 140 cycles per year based on a weighted average of dishwasher usage in the Mid-Atlantic Region derived from the 2009 RECs data; <http://205.254.135.7/consumption/residential/data/2009/>

6.0	= (700 – 490) * 0.001336	0.28

Incremental Cost
The lifecycle NPV incremental capital cost for this time of sale measure is \$0⁵⁹⁷.

Measure Life
The measure life is assumed to be 10 years⁵⁹⁸.

Operation and Maintenance Impacts
n/a

⁵⁹⁷ Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”
⁵⁹⁸ ENERGY STAR Dishwasher Calculator, see ‘EnergyStarCalculatorConsumerDishwasher.xls’.

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Shell Savings End Use

Air sealing

Unique Measure Code: RS_SL_RF_AIRSLG_0711

Effective Date: June 2014

End Date: TBD

Measure Description

This measure characterization provides a method of claiming both heating and cooling (where appropriate) savings from the improvement of a residential building's air-barrier, which together with its insulation defines the thermal boundary of the conditioned space.

The measure assumes that a trained auditor, contractor or utility staff member is on location, and will measure and record the existing and post air-leakage rate using a blower door in accordance with industry best practices⁵⁹⁹. Where possible, the efficiency of the heating and cooling system used in the home should be recorded, but default estimates are provided if this is not available.

This is a retrofit measure.

Definition of Baseline Condition

The existing air leakage prior to any air sealing work should be determined using a blower door.

Definition of Efficient Condition

⁵⁹⁹ See BPI Building Analyst and Envelope Professional standards, http://www.bpi.org/standards_approved.aspx

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Air sealing materials and diagnostic testing should meet all program eligibility qualification criteria. The post air sealing leakage rate should then be determined using a blower door.

Annual Energy Savings Algorithm

Total Annual Savings

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

Cooling savings from reduction in Air Conditioning Load:

$$\Delta kWh_{cool} = [(((CFM50_{Exist} - CFM50_{New}) / N_{cool}) * 60 * CDH * DUA * 0.018) / 1,000 / \eta_{Cool}] * LM$$

Where:

<i>CFM50_{exist}</i>	= Blower Door result (CFM ₅₀) prior to air sealing = actual
<i>CFM_{new}</i>	= Blower Door result (CFM ₅₀) after air sealing = actual
<i>N-cool</i>	= conversion from CFM ₅₀ to CFM _{Natural} ⁶⁰⁰

⁶⁰⁰ N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). Since there is minimal stack effect due to low delta T, the height of the building is not included in determining n-factor for cooling savings.

<http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122>

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= dependent on location and number of stories:⁶⁰¹

Location	N_cool (by # of stories)			
	1	1.5	2	3
Wilmington, DE	38.4	34.0	31.2	27.6
Baltimore, MD	38.4	34.0	31.2	27.6
Washington, DC	40.3	35.7	32.7	29.0

CDH

= Cooling Degree Hours⁶⁰²

= dependent on location:

Location	Cooling Degree Hours (75°F set point)
Wilmington, DE	7,514
Baltimore, MD	9,616
Washington, DC	13,178

⁶⁰¹ N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

⁶⁰² Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used), each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/by_state_and_city.html)

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DUA

0.018

η_{Cool}

= Discretionary Use Adjustment⁶⁰³

= 0.75

= The volumetric heat capacity of air (BTU/ft³°F)

= Efficiency in SEER of Air Conditioning equipment

= actual. If not available, use⁶⁰⁴:

Age of Equipment	SEER Estimate
Before 2006	10
After 20062006-2022	13
After 2023	15

LM

= Latent Multiplier to account for latent cooling demand⁶⁰⁵

Location	LM
Wilmington, DE	4.09
Baltimore, MD	3.63
Washington, DC	3.63

Illustrative example – do not use as default assumption

⁶⁰³ To account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75 °F. Based on Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

⁶⁰⁴ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

⁶⁰⁵ Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

A single story home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta kWh_{cool} = [(((3,400 - 2,250) / 38.4) * 60 * 7,514 * 0.75 * 0.018) / 1,000 / 12] * 4.09$$
$$= 62.1 \text{ kWh}$$

Heating savings for homes with electric heat (Heat Pump or resistance):

$$\Delta kWh_{heat} = (((CFM50Exist - CFM50New) / N_{heat}) * 60 * 24 * HDD * 0.018) / 1,000,000 / \eta_{Heat}) * 293.1$$

Where:

N_{heat}

= conversion from CFM_{50} to $CFM_{Natural}$

= Based on location and number of stories⁶⁰⁶:

Location	N_heat (by # of stories)			
	1	1.5	2	3
Wilmington, DE	24.5	21.7	19.9	17.6

⁶⁰⁶ N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegisis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30-year climate normals. For more information, see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

Baltimore, MD	25.1	22.3	20.4	18.1
Washington, DC	25.7	22.7	20.8	18.5

HDD = Heating Degree Days
= dependent on location⁶⁰⁷

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

η_{Heat} = Efficiency in COP of Heating equipment
= actual. If not available, use⁶⁰⁸:

System Type	Age of Equipment	HSPF Estimate	COP Estimate ⁶⁰⁹
Heat Pump	Before 2006	6.8	2.00

⁶⁰⁷ The 10-year average annual heating degree day value is calculated for each location, using a balance point for heating equipment use of 60 degrees (based on data obtained from <http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm>). The 60-degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

⁶⁰⁸ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate.

⁶⁰⁹ To convert HSPF to COP, divide the HSPF rating by 3.413.

	After 2006	7.7	2.26
Resistance	n/a	n/a	1.00

293.1 = Converts MMBTU to kWh

Illustrative example – do not use as default assumption
A two-story home in Wilmington, DE with a heat pump with COP of 2.5, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta \text{kWh}_{\text{heat}} = [(((3,400 - 2,250) / 24.5) * 60 * 24 * 3,275 * 0.018) / 1,000,000 / 2.5] * 293.1$$
$$= 467.1 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW}_{\text{cool}} = \Delta \text{kWh} / \text{FLH}_{\text{cool}} * \text{CF}$$

Where:
FLH_{cool} = Full Load Cooling Hours
= Dependent on location as below:

Location	FLH _{cool}
Wilmington, DE	524 ⁶¹⁰

⁶¹⁰ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

	<table><tr><td>Baltimore, MD</td><td>542⁶¹¹</td></tr><tr><td>Washington, DC</td><td>681</td></tr></table>	Baltimore, MD	542 ⁶¹¹	Washington, DC	681
Baltimore, MD	542 ⁶¹¹				
Washington, DC	681				
<i>CF_{SSP}</i>	= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday) = 0.69 ⁶¹²				
<i>CF_{PJM}</i>	= PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather = 0.66 ⁶¹³				

Illustrative example – do not use as default assumption
A single story home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta kW = 62.1 / 524 * 0.69$$
$$= 0.08 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

⁶¹¹ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.
⁶¹² Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.
⁶¹³ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

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$$\Delta \text{MMBTU} = (((\text{CFM}_{50\text{Exist}} - \text{CFM}_{50\text{New}}) / \text{N-heat}) * 60 * 24 * \text{HDD} * 0.018) / 1,000,000 / \eta_{\text{Heat}}$$

Where:

N-heat

= conversion from CFM_{50} to $\text{CFM}_{\text{Natural}}$
= Based on location and number of stories⁶¹⁴.

Location	N_heat (by # of stories)			
	1	1.5	2	3
Wilmington, DE	24.5	21.7	19.9	17.6
Baltimore, MD	25.1	22.3	20.4	18.1
Washington, DC	25.7	22.7	20.8	18.5

HDD

= Heating Degree Days

⁶¹⁴ N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, *Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30-year climate normals. For more information, see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

= dependent on location⁶¹⁵

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

η_{Heat} = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)
= actual⁶¹⁶. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%⁶¹⁷.

⁶¹⁵ The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from <http://www.engr.udayton.edu/weather/>). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

⁶¹⁶ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (<http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>) or by performing duct blaster testing.

⁶¹⁷ The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%. The distribution efficiency default is based on assumption that 50% of duct work is inside the envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

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Illustrative example – do not use as default assumption
A single story home in Wilmington, DE with a 70% heating system efficiency, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta \text{MMBTU} = ((3,400 - 2,250) / 24.5) * 60 * 24 * 3,275 * 0.018) / 1,000,000 / 0.7$$
$$= 5.7 \text{ MMBTU}$$

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this retrofit measure should be the actual installation and labor cost to perform the air sealing work.

Measure Life
The measure life is assumed to be 15 yrs⁶¹⁸.

Operation and Maintenance Impacts
n/a

⁶¹⁸ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

Attic/ceiling/roof insulation

Unique Measure Code: RS_SL_RF_ATTICI_0711

Effective Date: June 2014

End Date: TBD

Measure Description

This measure characterization is for the installation of new insulation in the attic/roof/ceiling of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and where possible the efficiency of the heating and cooling system used in the home.

This is a retrofit measure.

Definition of Baseline Condition

The existing insulation R-value should include the total attic floor / roof assembly. An R-value of 5 should be assumed for the roof assembly plus the R-value of any existing insulation⁶¹⁹. Therefore, if there is no insulation currently present, the R-value of 5 should be used.

Definition of Efficient Condition

The new insulation should meet any qualification criteria required for participation in the program. The new insulation R-value should include the total attic

⁶¹⁹ The R-5 assumption for roof assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p27. The attic floor and roof should be modeled as a system including solar gains and attic ventilation, and R-5 is the standard assumption for the thermal resistance of the whole attic/roof system.

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floor /roof assembly and include the effective R-value of any existing insulation that is left in situ.

Annual Energy Savings Algorithm

Savings from reduction in Air Conditioning Load:

$$\Delta kWh = ((1/R_{exist} - 1/R_{new}) * CDH * DUA * Area) / 1,000 / \eta_{Cool} * Adj_{cool}$$

Where:

- R_{exist}* = R-value of roof assembly plus any existing insulation
= actual (minimum of R-5)
- R_{new}* = R-value of roof assembly plus new insulation
= actual
- CDH* = Cooling Degree Hours⁶²⁰
= dependent on location:

Location	Cooling Degree Hours (75°F set point)
Wilmington, DE	7,514
Baltimore, MD	9,616
Washington, DC	13,178

⁶²⁰ Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used), each hour of the year. Hourly temperature data obtained from TMY3 data (<http://rredc.nrel.gov/solar/>)

DUA = Discretionary Use Adjustment⁶²¹
 = 0.75
Area = square footage of area covered by new insulation
 = actual
η_{Cool} = Efficiency in SEER of Air Conditioning equipment
 = actual. If not available, use⁶²²:

Age of Equipment	SEER Estimate
Before 2006	10
~~After 2006~~ 2006 - 2022	13
After 2023	15

Adj_{cool} = 0.8⁶²³

Illustrative example – do not use as default assumption

Insulating 1200 square feet of attic from R-5 to R-30 in a home with a 12 SEER central Air Conditioning unit in Baltimore, MD.

$$\Delta \text{kWh} = ((1/5 - 1/30) * 9,616 * 0.75 * 1,200) / 1,000 / 12 * 0.8$$

$$= 96 \text{ kWh}$$

⁶²¹ To account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75 °F. Based on Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

⁶²² These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

⁶²³ From Illinois TRM, 9 as demonstrated in two years of metering evaluation by Opinion Dynamics. Adjusts savings derived through engineering algorithms to actual savings measured in field.

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Savings for homes with electric heat (Heat Pump or resistance):

$$\Delta kWh = (((1/R_{exist} - 1/R_{new}) * HDD * 24 * Area) / 1,000,000 / \eta_{Heat}) * 293.1 * Adj_{heat}$$

HDD = Heating Degree Days
= dependent on location⁶²⁴

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

1,000,000 = Converts BTU to MMBTU
η_{Heat} = Efficiency in COP of Heating equipment
= actual. If not available, use⁶²⁵:

System Type	Age of Equipment	HSPF Estimate	COP Estimate
Heat Pump	Before 2006	6.8	2.00

⁶²⁴ The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from <http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm>). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

⁶²⁵ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

	After 2006	7.7	2.26
Resistance	n/a	n/a	1.00

293.1 = Converts MMBTU to kWh

Adjheat = 0.6⁶²⁶

Illustrative example – do not use as default assumption
Insulating 1200 square feet of attic from R-5 to R-30 in a home with a 2.5COP Heat Pump in Baltimore, MD.

$$\Delta kWh = (((1/5 - 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 2.5) * 293.1 * 0.6$$
$$= 1,167 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / FLH_{cool} * CF$$

Where:

FLH_{cool}

= Full Load Cooling Hours

= Dependent on location as below:

Location	FLH _{cool}

⁶²⁶ From Illinois TRM, 9 as demonstrated in two years of metering evaluation by Opinion Dynamics

Wilmington, DE	524 ⁶²⁷
Baltimore, MD	542 ⁶²⁸
Washington, DC	681

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69⁶²⁹

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.66⁶³⁰

Illustrative example – do not use as default assumption

Insulating 1200 square feet of attic from R-5 to R-30 in a home with a 12 SEER central Air Conditioning unit in Baltimore, MD.

$$\Delta kW = 96 / 542 * 0.69$$

⁶²⁷ Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

⁶²⁸ Based on average of 5 utilities in Maryland from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program.” April 4, 2014, table 30, page 48.

⁶²⁹ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

⁶³⁰ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

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= 0.12 kW

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBTU} = ((1/R_{\text{exist}} - 1/R_{\text{new}}) * \text{HDD} * 24 * \text{Area}) / 1,000,000 / \eta_{\text{Heat}} * \text{Adj}_{\text{heat}}$$

Where:

HDD = Heating Degree Days
= dependent on location⁶³¹

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

η_{Heat} = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)

⁶³¹ The 10-year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from <http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm>). The 60-degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

= actual⁶³². If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%⁶³³.

Adjheat = 0.60⁶³⁴

Illustrative example – do not use as default assumption
Insulating 1200 square feet of attic from R-5 to R-30 in a home with a 75% efficiency heating system in Baltimore, MD.

$$\Delta \text{MMBTU} = ((1/5 - 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 0.75 * .60$$
$$= 13 \text{ MMBTU}$$

Annual Water Savings Algorithm
n/a

⁶³² Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (<http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>) or by performing duct blaster testing.

⁶³³ The equipment efficiency default is based on data provided by GAMA during the Federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%. The distribution efficiency default is based on assumption that 50% of duct work is inside the envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

⁶³⁴ From Illinois TRM, 9 as demonstrated in two years of metering evaluation by Opinion Dynamics. Factor adjusts predicted values from engineering estimates to better match the actual values as measured in the field.

Incremental Cost

The incremental cost for this retrofit measure should be the actual installation and labor cost to perform the insulation work.

Measure Life

The measure life is assumed to be 25 years⁶³⁵.

Operation and Maintenance Impacts

n/a

⁶³⁵ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Efficient Windows - Energy Star, Time of Sale

Unique Measure Code(s): RS_SL_TOS_WINDOW_0510
Effective Date: June 2014
End Date: TBD

Measure Description

This measure describes the purchase of Energy Star Windows (u-0.32; SHGC-0.40 minimum requirement for North Central region) at natural time of replacement or new construction outside of the Energy Star Homes program. This does not relate to a window retrofit program. Measure characterization assumes electric heat- either resistance or heat pump.

Definition of Baseline Condition

The baseline condition is a standard double pane window with vinyl sash, (u-0.49 SHGC-0.58).

Definition of Efficient Condition

The efficient condition is an ENERGY STAR window (u-0.32; SHGC-0.40 minimum requirement for North Central region).

Annual Energy Savings Algorithm ⁶³⁶

Heating kWh Savings (Electric Resistance) = 356 kWh per 100 square feet window area

⁶³⁶ Based on REMRate modeling of New Jersey baseline existing home moved to Baltimore climate with electric furnace or air source heat pump HSPF 2.0, SEER 10 AC. Ducts installed in un-conditioned basement. Duct leakage set at RESNET/HERS qualitative default.

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Heating kWh Savings (Heat Pump COP 2.0) = 194 kWh per 100 square feet window area

Cooling kWh Savings (SEER 10) = 205 kWh per 100 square feet window area

Summer Coincident Peak kW Savings Algorithm

$\Delta kW_{cooling} = \Delta kW_{REM} * CF$

Where:

- ΔkW_{REM}

= Delta kW calculated in REMRate model
= 0.12 kW per 100 square feet window area
- CF_{SSP}

= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69⁶³⁷
- CF_{PJM}

= PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.66⁶³⁸

$\Delta kW_{SSP \text{ cooling}} = 0.12 * 0.69$

⁶³⁷ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

⁶³⁸ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

= 0.083 kW per 100 square feet of windows

$\Delta kW_{PJM} \text{ cooling} = 0.12 * 0.66$

= 0.079 kW per 100 square feet of windows

Annual Fossil Fuel Savings Algorithm
n/a for homes with electric heat.

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this time of sale measure is assumed to be \$2.20 square foot of windows.⁶³⁹

Measure Life
The measure life is assumed to be 25 years.⁶⁴⁰

Operation and Maintenance Impacts
n/a

⁶³⁹ \$33 per 15 square-foot window. Energy Star for Windows, Doors and Skylights Version 6.0 Criteria Revision, Review of Cost Effectiveness Analysis, July 2013, p. 6. Accessed April 25, 2017 at https://www.energystar.gov/sites/default/files/ESWDS-ReviewOfCost_EffectivenessAnalysis.pdf.
⁶⁴⁰ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. <http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Crawl Space Insulation and Encapsulation

Unique Measure Code(s): RS_SL_RF_CRLINS_0616

Effective Date: June 2016

End Date: TBD

Measure Description

This measure relates to the insulation and/or encapsulation to a crawl space under a single family home. This measure also allows for the possibility that the crawl space will be encapsulated. This encapsulation in effect changes the crawlspace from an unconditioned space to a conditioned space, thus eliminating losses from any duct work that may run through the space.

Definition of Baseline Condition

The baseline depends on site specific conditions. However, it is most likely to be an unencapsulated, uninsulated crawlspace.

Definition of Efficient Condition

The efficient condition is a crawlspace that is insulated and/or encapsulated.

Annual Energy Savings Algorithm⁶⁴¹

$$\Delta kWh = kWh_{cooling} + kWh_{heating} + kWh_{ducts}$$

Where:

⁶⁴¹ When possible, energy savings should be determined through a custom analysis such as building simulation. If that option is not feasible, savings may be estimated using the algorithms in this section

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$kWh_{cooling}$

= reduction in cooling requirement. Only applicable to homes with central cooling

$$= ((1 / R\_Old\_AG - 1 / (R\_Old\_AG + R\_Added\_AG)) * L\_Basement\_Wall * H\_Basement\_Wall\_AG * (1 - Framing\_Factor) * CDH * DUA) / (1000 * \eta_{Cool}) * Adj_{Basementcool}$$

Where:

- R_Old_AG

= R-Value of foundation wall above grade

= Actual, if unknown assume 1.0⁶⁴²
- R_Added_AG

= R-Value of additional insulation
- $L\_Basement\_Wall$

= Length of basement wall around the insulated perimeter
- $H\_Basement\_Wall\_AG$

= Height of basement wall above grade
- $Framing\_Factor$

= Adjustment to account for area of framing if cavity insulation

= 0% if spray foam or rigid foam

= 25% if studs and cavity insulation⁶⁴³
- 24

= converts days to hours
- CDH

= Cooling Degree Hours⁶⁴⁴

= dependent on location:

⁶⁴² 1448 ORNL Builders Foundation Handbook, crawl space data from Table 5-5: Initial Effective R-values for Uninsulated Foundation System and Adjacent Soil, 1991, <http://www.ornl.gov/sci/roofs+walls/foundation/ORNLCON-295.pdf>

⁶⁴³ ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

⁶⁴⁴ Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used), each hour of the year. Hourly temperature data obtained from TMY3 data (<http://rredc.nrel.gov/solar/>)

Location	Cooling Degree Hours (75°F set point)
Wilmington, DE	7,514
Baltimore, MD	9,616
Washington, DC	13,178

DUA

= Discretionary Use Adjustment, to account for the fact that people do not always operate AC when conditions call for it.

= 0.75⁶⁴⁵

η_{Cool}

= Efficiency in SEER of Cooling Equipment.

= Actual. If unknown use⁶⁴⁶:

Age of Equipment	SEER Estimate
Before 2006	10
~~After 2006~~ 2006 – 2022	~~13~~ 13
After 2023	15

$Adj_{Basementcool}$

= Adjustment to take into account prescriptive algorithms overclaiming savings

= 80%⁶⁴⁷

⁶⁴⁵ This factor's source is: Energy Center of Wisconsin, May 2008 metering study; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research", p31.

⁶⁴⁶ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

⁶⁴⁷ As determined by Illinois Technical Resource Manual

$kWh_{heating}$

= Reduction in annual heating requirement, if electric heat (resistance or heat pump)

$$= (kWh_{AG} + kWh_{BG}) * Adj_{Basement}$$

Where:

kWh_{AG}

= Savings from insulation on walls or crawlspaces above grade

$$= ((1/R_{Old\_AG} - 1/(R_{Old\_AG} + R_{Added})) * L_{Basement\_Wall} * H_{Basement\_Wall\_AG} * (1 - Framing\_Factor) * HDD * 24) / (3412 * \eta_{Heat})$$

kWh_{BG}

= Savings from insulation on walls or crawlspaces below grade

$$= ((1/R_{Old\_BG} - 1/(R_{Old\_BG} + R_{Added})) * L_{Basement\_Wall} * H_{Basement\_Wall\_BG} * (1 - Framing\_Factor) * HDD * 24) / (3412 * \eta_{Heat})$$

Where:

HDD

= Heating Degree Days

= Dependent on location:⁶⁴⁸

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275

⁶⁴⁸ The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from <http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm>). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

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Baltimore, MD	3,457
Washington, DC	2,957

3412
 η_{Heat}

= Converts kWh to BTU
= Efficiency of Heating system, in COP. If not available, use⁶⁴⁹:

System Type	Age of Equipment	HSPF Estimate	COP Estimate
Heat Pump	Before 2006	6.8	2.00
	After 2006	7.7	2.26
Resistance	n/a	n/a	1.00

R_{Old_BG}

= R-Value of Wall below Grade
= Dependent on depth of foundation⁶⁵⁰

Depth below grade (ft)	0	1	2	3	4	5	6	7	8
Earth R-value	2.44	4.5	6.3	8.4	10.44	12.66	14.49	17	20
Average Earth R-value	2.44	3.16	3.79	4.40	4.97	5.53	6.07	6.60	7.13
Total Below Grade R-value (earth + R-1.0 foundation) default	3.44	4.47	5.41	6.41	7.42	8.46	9.46	10.53	11.69

⁶⁴⁹ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate

⁶⁵⁰ Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

$H_{Basement\_Wall\_BG}$ = Height of basement wall below grade
 $Adj_{Basementheat}$ = Adjustment to account for prescriptive algorithms overclaiming savings
= 60%⁶⁵¹
 kWh_{ducts} = electric savings from loss of duct leaks, if more than 50% of ducts are in a conditioned area
= $kWh_{duct\_cool} + kWh_{duct\_heat}$

And:

kWh_{duct_cool} = $Hours\_Cool * BTU/Hour * (1 / SEER) * Duct\_Factor / 1000$
 kWh_{duct_heat} = $Hours\_Heat * BTU/Hour * (1/HSPF) * Duct\_Factor / 1,000$

Where:

$Hours\_Cool$ = Full load cooling hours

Dependent on location as below:

Location	Run Hours

⁶⁵¹ As determined by the Illinois Technical Resource Manual.

Wilmington, DE	524 ⁶⁵²
Baltimore, MD	542 ⁶⁵³
Washington, DC	681

BTU/Hour = Size of equipment in BTU/hour (note 1 ton = 12,000BTU/hour)

= Actual installed

SEER = Seasonal Efficiency of conditioning equipment
= actual installed

Duct_Factor = Factor to account for elimination of duct losses from encapsulation
=0.05

Hours_Heat = Full Load Heating Hours
= Dependent on location as below:

Location	FLHheat
Wilmington, DE	935 ⁶⁵⁴
Baltimore, MD	866 ⁶⁵⁵
Washington, DC	822

⁶⁵² Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (542 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator.

(http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

⁶⁵³ Based on average of 5 utilities in Maryland from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Residential HVAC Program." April 4, 2014, table 30, page 48.

gs_calc/ASHP_Sav_Calc.xls)

, table 30, page 48.

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HSPF = Heating Seasonal Performance Factor of heating equipment
= Actual

Illustrative examples – do not use as default assumption

A single family home in Wilmington is getting its crawlspace insulated with R-13 spray foam and encapsulated. The crawlspace currently has an R-value of 2.25, and a significant portion of the home’s ductwork runs through the crawlspace. The house has a 20x25 footprint, and the crawl space walls are 7 feet tall, 3 of which are above grade. The HVAC unit is a heat pump with 13 SEER and 2.26 COP.

$$\begin{aligned}
 \Delta \text{kWh} &= \text{kWh}_{\text{cooling}} + \text{kWh}_{\text{heating}} + \text{kWh}_{\text{ducts}} \\
 \text{kWh}_{\text{cooling}} &= ((1/2.25 - 1/(2.25 + 13)) * (20*2 + 25*2) * 3 * (1-0) * 7514 * 0.75) / (1,000 * 13) * 0.8 \\
 &= 35 \text{ kWh} \\
 \text{kWh}_{\text{heating}} &= (((1/2.25 - 1/(2.25 + 13)) * (20*2 + 25*2) * 3 * (1-0) * 3275 * 24) / (3412 * 2.26)) + [((1/(6.42 + 2.25) - 1/(6.42 + 2.25 + 13)) * (20*2 + 25*2) * 4 * (1-0) * 3275 * 24) / (3412 * 2.26)] * 0.6 \\
 &= 722 \text{ kWh} \\
 \text{kWh}_{\text{ducts}} &= 524 * 36,000 * (1/13) * 0.05 / 1000 + 935 * 36,000 * (1/8) * 0.05 / 1,000 \\
 &= 283 \text{ kWh} \\
 \Delta \text{kWh} &= 35 + 722 + 283 \\
 &= 1,040 \text{ kWh}
 \end{aligned}$$

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Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kWh_{cooling} / \text{Hours\_Cool} * CF$$

Where:

CF_{SSP}

CF_{PJM}

= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)

= 0.69⁶⁵⁶

= PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather

= 0.66⁶⁵⁷

Illustrative examples – do not use as default assumption

For the house described above:

$$\Delta kW = 35 / 524 * 0.69$$
$$= 0.046 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If Natural Gas heating:

$$\Delta \text{therms} = (\text{therms}_{AG} + \text{therms}_{BG}) * Adj_{Basement} + \text{therms}_{duct}$$

Where:

⁶⁵⁶ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

⁶⁵⁷ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

$therms_{AG}$

$therms_{BG}$

$therms_{duct}$

= Savings from insulation on walls or crawlspaces above grade

= Savings from insulation on walls or crawlspaces below grade

= Hours_Heat * BTU/Hour * AFUE * Duct_Factor / 100,000

Where:

Hours_heat = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ⁶⁵⁸
Baltimore, MD	620 ⁶⁵⁹
Washington, DC	528 ⁶⁶⁰

⁶⁵⁸ Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

⁶⁵⁹ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHeat assumption.

⁶⁶⁰ Full load heating hours derived by adjusting FLH_{heat} for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

η_{Heat} = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)
 = actual⁶⁶¹. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%⁶⁶².

Other factors as defined above

Illustrative examples – do not use as default assumption

For the house described above, but with a central furnace:

$$\begin{aligned} \Delta \text{therms} &= (\text{therms}_{AG} + \text{therms}_{BG}) * Adj_{\text{Basement}} + \text{therms}_{\text{duct}} \\ \text{therms}_{AG} &= ((1/2.25 - 1/(2.25+13)) * (20*2+25*2) * 3 * (1-0) * 3275 \\ &\quad * 24) / (100,067 * 0.66) \\ &= 122 \text{ therms} \\ \text{therms}_{BG} &= ((1/(2.25+6.42) - 1/(2.25+6.42+13)) * (20*2+25*2) * 4 * \\ &\quad (1-0) * 3275 * 24) / (100,067 * 0.66) \end{aligned}$$

⁶⁶¹ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (<http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>) or by performing duct blaster testing.

⁶⁶² The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%. The distribution efficiency default is based on assumption that 50% of duct work is inside the envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

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$therms_{duct}$

$\Delta therms$

$= 30\;therms$

$= 848 * 100,000 * .84 * 0.05 / 100,000$

$= 36\;therms$

$= (122 + 30) * 0.6 + 36$

$= 127$

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this retrofit measure should be the actual installation and labor cost to perform the insulation work.

Measure Life
The expected measure life is assumed to be 25 years.⁶⁶³

Operation and Maintenance Impacts
n/a

⁶⁶³ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

Residential Retrofit Comprehensive Insulation and Air-Sealing

Unique Measure Code: RS_SL_RF_COMP-INS-AS_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This retrofit measure characterization refers to the installation of insulation in any thermal envelope assembly when air leakage reduction is also included in the service. The measure assumes that a qualified inspector will measure and record the existing and new conditions for all improved components including area measurements, depth and type of insulation, and pre/post air leakage measurements obtained through the use of a blower door test that depressurizes the building to -50 Pascals. Heating and cooling system efficiencies must also be collected. Air-sealing may also include addressing duct leakage. Testing and inspection should be performed in accordance with Building Performance Institute (BPI) standards.⁶⁶⁴

Definition of Baseline Condition

The baseline condition is the existing, measured and evaluated insulation, and tested air leakage value.

Definition of Efficient Condition

The efficient condition is the upgraded home with additional insulation and air leakage reduction. Improvements should meet any qualification criteria required for participation in the program, in addition to all relevant BPI tests and protocols.

⁶⁶⁴ <https://bpi.org/standards>

Reporting should include insulation R-values and areas, along with improved air leakage CFM50 based on blower door testing.

Annual Energy Savings Algorithm

Comprehensive, interactive energy saving is derived from approved software package where the user inputs a minimum set of technical data about the house and the software calculates building heating and cooling loads and other key parameters. The building model is based on thermal transfer, internal gains, and a variable-based heating/cooling degree day/hour climate model. This provides an initial estimate of energy use that may be compared with actual billing data to adjust as needed for existing conditions. Then, specific recommendations for improvements are added and savings are calculated using measure-specific heat transfer algorithms. Rather than using a fixed degree day approach, the building model estimates both heating degree days and cooling degree hours based on the actual characteristics and location of the house to determine the heating and cooling balance point temperatures. Savings from shell measures use standard U-value, area, and degree day algorithms. Air leakage savings use site-specific seasonal N-factors to convert measured leakage to seasonal energy impacts.

Savings are based on standard algorithms, taking into account operating conditions and pre- and post-retrofit energy consumption. Interactivity between architectural and mechanical measures is always included for accurate savings results.

Summer Coincident Peak kW Savings Algorithm

Demand savings will be an output of the software model. It can then be adjusted externally for appropriate demand reductions.

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The measure life of insulation is assumed to be 25 years⁶⁶⁸.

Operation and Maintenance Impacts

n/a

⁶⁶⁸ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Residential New Construction Comprehensive Thermal Improvements

Unique Measure Code: RS_SL_TOS_COMPRNC_0619
Effective Date: June 2019
End Date: TBD

Measure Description

This characterization applies to the Residential New Construction market and refers to program-level insulation and air leakage standards. This single measure is a comprehensive approach to multi-measure savings claims. Heating and cooling system efficiencies, along with duct leakage, have interactive effects with thermal improvements and must also be included in the analysis. Testing and inspection should be performed in accordance with Residential Energy Services Network (RESNET) standards⁶⁶⁹.

Definition of Baseline Condition

The baseline condition is the code-level (or user-defined reference home) insulation and air leakage values.

Definition of Efficient Condition

The efficient condition is the new home with improved insulation and air leakage meeting qualification criteria required for participation in the program.

Annual Energy Savings Algorithm

⁶⁶⁹ <http://www.resnet.us/professional/standards>

Comprehensive, interactive energy saving is derived from approved software package where the user inputs a minimum set of technical data about the house and the software calculates building heating and cooling loads and other key parameters. The building model is based on thermal transfer, internal gains, and a variable-based heating/cooling degree day/hour climate model. This provides an initial estimate of energy use that may be compared against the baseline home. Specific improvements are then added and savings are calculated using measure-specific heat transfer algorithms. Savings from shell measures use standard U-value, area, and degree day algorithms. Infiltration savings use site-specific seasonal N-factors to convert measured leakage to seasonal energy impacts.

Savings are based on standard algorithms. Interactivity between architectural and mechanical measures is included for accurate savings results.

Summer Coincident Peak kW Savings Algorithm

Demand savings is an output of the software model. It can then be adjusted externally for appropriate demand reductions.

CF_{SSP}

= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)

= 0.69⁶⁷⁰

CF_{PJM}

= PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather

= 0.66⁶⁷¹

⁶⁷⁰ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the Maryland Peak Definition coincidence factor is 0.69.

⁶⁷¹ Based on BG&E “Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps” research, the PJM Peak Definition coincidence factor is 0.66.

Annual Fossil Fuel Savings Algorithm

Fossil fuel savings are calculated by software model.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost will vary for each project.

Measure Life

The measure life of air sealing is assumed to be 15 years⁶⁷²

The measure life of insulation is assumed to be 25 years⁶⁷³.

Operation and Maintenance Impacts

n/a

⁶⁷² Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

⁶⁷³ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

<http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007>.

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Pool Pump End Use

High Efficiency Pool Pump

Unique Measure Code: RS_PP_TOS_PPVAR_0711

Effective Date: June 2014

End Date: TBD

Measure Description

This measure describes the purchase of a standard-size, ENERGY STAR two-speed or variable speed residential outdoor swimming pool pump in place of a standard efficiency pump of equivalent horsepower. The measure could be installed in either an existing or new swimming pool. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a standard efficiency residential outdoor swimming pool pump meeting federal energy conservation standards.⁶⁷⁴

Definition of Efficient Condition

The efficient condition is a two-speed or variable speed residential outdoor pool pump meeting ENERGY STAR minimum qualifications.

Annual Energy Savings Algorithm⁶⁷⁵

⁶⁷⁴ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.465 (2021).

⁶⁷⁵ The methodology and all assumptions (unless otherwise noted) are sourced from the ENERGY STAR Pool Pump Calculator and assume a pool size of 22,000 gallons and 2.0 turnovers per day. "Savings Calculator for an ENERGY STAR Certified Inground Pool Pump." April 2020.

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$$\Delta kWh = ((VOL * TPD * Days) * ((1/WEF_{Base}) - (1/WEF_{EE}))) / 1000$$

Where:

VOL = pool volume in gallons, default = 22,000 gallons

TPD = pool water turnovers per day, default = 2.0

WEF_{Base} = Weighted Energy Factor of baseline pump (gal/Wh), dependent on hydraulic horsepower (hhp) as calculated per table below:⁶⁷⁶

Dedicated-purpose pool pump variety	WEF _{BASE}
Self-priming pool filter pumps	-2.30 * hhp + 6.59
Non-self-priming pool filter pumps	4.60, for hhp ≤ 0.13 hp; -0.85 * ln (hhp) + 2.87, for hhp > 0.13 hp

WEF_{EE} = Weighted Energy Factor of the efficient pump (gal/Wh), dependent on hydraulic horsepower (hhp). Actual installed.

= See table below for default values:

Hydraulic Horsepower (hhp)	WEF _{EE}
0.72	8.7

⁶⁷⁶ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.465 (2021).

0.95	8.9
1.18	9.3
1.25	7.4
1.65	7.1

Days = Number of days per year that the swimming pool is operational,
default = 100 (assumed typical operation in a cool climate)

1000 =Watts per kilowatt

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{EE}) * CF^{677}$$

Where:

- kW_{Base} = Connected load of baseline motor
= 1.3 kW
- kW_{EE} = Connected load of variable speed motor
= 0.087 kW
- CF_{SSP} = Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)
= 0.20⁶⁷⁸

⁶⁷⁷ All factors are based on data from INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

⁶⁷⁸ Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

CF_{PJM} = PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.27⁶⁷⁹

$$\Delta kW_{SSP} = (1.3 - 0.087) * 0.20$$
$$= 0.24 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3 - 0.087) * 0.27$$
$$= 0.34 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this time of sale measure is assumed to be \$175 for a two speed pool pump motor⁶⁸⁰ and \$549 for a variable speed pool pump motor⁶⁸¹.

Measure Life

⁶⁷⁹ Ibid.
⁶⁸⁰ Based on review of Lockheed Martin pump retail price data, July 2009.
⁶⁸¹ Assumption used in Energy Star pool pump calculator, based on “EPA research on available models, 2013.” Accessed April 25, 2017 at https://www.energystar.gov/products/other/pool_pumps.

The measure life is assumed to be 10 yrs⁶⁸².

Operation and Maintenance Impacts
n/a

⁶⁸² VEIC estimate.

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*Plug Load End Use***Tier 1 Advanced Power Strip****Unique Measure Code:** RS_PL_TOS_APS_0711**Effective Date:** June 2014**End Date:** TBD**Measure Description**

This measure describes savings associated with the purchase and use of a Current-Sensing Master/Controlled Advanced Power Strip (APS). 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 characterization provides a single prescriptive savings assumption based on office and entertainment savings from a 2011 NYSERDA Advanced Power Strip Research Report and weightings and in service rates based on EmPower evaluations.

Definition of Baseline Condition

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

Definition of Efficient Condition

The efficient case is the use of a Current-Sensing Master/Controlled Advanced Power Strip.

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Annual Energy Savings Algorithm

$$\Delta kWh = (kWh_{office} * Weighting_{Office} + kWh_{Ent} * Weighting_{Ent}) * ISR$$

Where:

- kWh_{office}

= Estimated energy savings from using an APS in a home office

= 31.0 kWh⁶⁸³
- Weighting_{Office}

= Relative penetration of computers

= 41%⁶⁸⁴
- kWh_{Ent}

= Estimated energy savings from using an APS in a home entertainment system

⁶⁸³ NYSERDA 2011, Advanced Power Strip Research Report, <http://www.nyserda.ny.gov/-/media/Files/EERP/Residential/Energy-Efficient-and-ENERGY-STAR-Products/Power-Management-Research-Report.pdf>. Note that estimates are not based on pre/post metering but on analysis based on frequency and consumption of likely products in active, standby and off modes. This measure should be reviewed frequently to ensure that assumptions continue to be appropriate.

⁶⁸⁴ EmPower 2012 Residential Retrofit evaluation

= 50.7 kWh

$$= 0.8^{689}$$

689 Ibid

$$\begin{aligned}\Delta kW &= (50.7/6,351) * 0.8 \\ &= 0.0064 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be \$18⁶⁹⁰.

Measure Life

The measure life is assumed to be 4 years⁶⁹¹.

Operation and Maintenance Impacts

n/a

⁶⁹⁰ IILSAG 2015 Analysis

⁶⁹¹ David Rogers, Power Smart Engineering, October 2008: "Smart Strip electrical savings and usability", p22. Assumes that the unit can only take one surge and then needs to be replaced.

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Clothes Dryer, (Upstream)

Unique Measure Code(s): RS_AP_TOS_RPPDRY_0616

Effective Date: June 2016

End Date: TBD

Measure Description

This measure relates to the upstream promotion of residential clothes dryer meeting the ENERGY STAR criteria through the Energy Star Retail Products Program. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers⁶⁹². ENERGY STAR provides criteria for both gas and electric clothes dryers.

Definition of Baseline Condition

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after June 1, 2015.

Definition of Efficient Condition

⁶⁹² ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011.

http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

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Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

Annual Energy Savings Algorithm

$\Delta kWh^{693} = kWh_{Base} - kWh_{ESTAR}$

Where:

- kWh_{BASE} = Baseline kWh consumption per year
= As presented in the table below
- kWh_{ESTAR} = ENERGY STAR kWh consumption per year
=As presented in the table below

⁶⁹³ Baseline energy consumption is based on a modified 2015 Federal Standard (available at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/36). The goal of the translation is to account for the use of the amended DOE test procedure 10 CFR 430, Subpart B, Appendix D2 which assesses energy efficiency as a result of clothes dryer automatic cycle termination controls. The DOE 2015 standard CEF values are based on the DOE Appendix D1 test. ENERGY STAR is requiring an updated DOE test, published in Appendix D2. On average, clothes dryers use more energy when tested under Appendix D2, and so the translation adjusts the D1 Federal standard to reflect the estimated average energy efficiency performance of minimally-compliant 2015 models under D2. The translation values (-16.6% for the electric standard and -13.9% for the gas dryers) are based on DOE testing published in their NOPR test procedure in January 2013. Performance requirements for ENERGY STAR certified clothes dryers can be found in the ENERGY STAR specifications (V 1.0) (available at: <http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%201%200%20Clothes%20Dryers%20Program%20Requirements.pdf>). Calculations assume 283 cycles per year and an 8.45 lb load for standard sized dryers (≥ 4.4 cu-ft capacity).

Product Category ⁶⁹⁴	kWh _{BASE}	kWh _{ESTAR}	kWh Savings
Vented Gas Dryer	42.10	34.36	7.74
Ventless or Vented Electric Dryer	768.92	608.49	160.44

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer.
=290 hours per year.⁶⁹⁵

CF = Summer Peak Coincidence Factor for measure
= 2.9%⁶⁹⁶

Annual Fossil Fuel Savings Algorithm

⁶⁹⁴ Savings values come from Energy Star Calculations. See ‘RPP Product Analysis 9-23-15.xlsx’

⁶⁹⁵ Assumes average of 56 minutes per cycle based on Ecova, ‘Dryer Field Study’, Northwest Energy Efficiency Alliance (NEEA) 2014

⁶⁹⁶ Consistent with coincidence factor of Clothes Washers; Metered data from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program.” March 21, 2014, page 36.

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

$$\Delta \text{MMBTU} = \text{MMBTU}_{\text{Base}} - \text{MMBTU}_{\text{STAR}}$$

Where:

- $\text{MMBTU}_{\text{BASE}}$ = Baseline MMBTU consumption per year
= As presented in the table below
- $\text{MMBTU}_{\text{ESTAR}}$ = ENERGY STAR MMBTU consumption per year
=As presented in the table below

Product Category ⁶⁹⁷	MMBTU _{BASE}	MMBTU _{ESTAR}	MMBTU Savings
Vented Gas Dryer	2.72	2.22	0.50

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for a time of sale ENERGY STAR clothes dryer is assumed to be \$75.⁶⁹⁸

Measure Life

⁶⁹⁷ Savings values come from Energy Star Calculations. See ‘RPP Product Analysis 9-23-15.xlsx’
⁶⁹⁸ Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”

The expected measure life is assumed to be 12 years⁶⁹⁹.

Operation and Maintenance Impacts

n/a

⁶⁹⁹ Based on Appliances Magazine (Appliance Magazine. US Appliance Industry: Market Value, Life Expectancy & Replacement Picture). Please note that this report provides slightly different average life expectancies for gas and electric. To minimize confusion, ENERGY STAR uses 12 years for both product types.

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Room Air Conditioners (Upstream)

Unique Measure Code(s): RS_HV_TOS_RPPRAC_0616

Effective Date: June 2016

End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a room air conditioning unit that meets the ENERGY STAR minimum qualifying efficiency specifications presented below:

Product Type and Class (BTU/hour)		Federal Standard with louvered sides (EER)	Federal Standard without louvered sides (EER)	ENERGY STAR with louvered sides (EER)	ENERGY STAR without louvered sides (EER)
Without Reverse Cycle	< 6,000	11.0	10.0	12.1	11.0
	6,000 to 7,999	11.0	10.0	12.1	11.0
	8,000 to 13,999	10.9	9.6	12.0	10.6
	14,000 to 19,999	10.7	9.5	12.0	10.5
	20,000 to 24,999	9.4	9.3	10.3	10.2
	>=25,000	9.0	9.4	9.9	10.3
With Reverse Cycle	<14,000	n/a	9.3	n/a	10.2
	>=14,000	n/a	8.7	n/a	9.6
	<20,000	9.8	n/a	10.8	n/a
	>=20,000	9.3	n/a	10.2	n/a
Casement only		9.5		10.5	

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Casement-Slider	10.4	11.4

Definition of Baseline Condition

The baseline condition is a window AC unit that meets the minimum federal efficiency standards as of June 1, 2014 presented above.⁷⁰⁰

Definition of Efficient Condition

The baseline condition is a window AC unit that meets the ENERGY STAR v4.0 as of October 26, 2015 presented above.⁷⁰¹

Annual Energy Savings Algorithm

ΔkWh^{702} = kWh_{Base} - kWh_{ESTAR}

Where:

kWh_{BASE} = Baseline kWh consumption per year
= see table below for calculated values

⁷⁰⁰ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

⁷⁰¹ <http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf>

⁷⁰² Baseline energy consumption is based on the federal standard for room air conditioners, available at: http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. The unit energy savings are calculated by taking a market share weighted average of the unit energy consumption of all product subtypes listed in the ENERGY STAR specification. See ‘RPP Product Analysis 9-23-15.xlsx’

kWh_{ESTAR} = ENERGY STAR kWh consumption per year
= see table below for calculated values

Location	Full-Load Cooling Hours	Savings (kWh/year)
Wilmington, DE	1,015	74.72
Baltimore, MD	1,050	77.30
Washington, DC	1,320	97.18

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = BTU/hour * (1/EER_{base} - 1/EER_{ee})/1000 * CF$

Where:

- CF = Summer Peak Coincidence Factor for measure
- CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.31⁷⁰³
- CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather

⁷⁰³ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

$$= 0.3^{704}$$

Using deemed values above:

$$\begin{aligned}\Delta kW_{\text{ENERGY STAR SSP}} &= (8500 * (1/10.9 - 1/11.3)) / 1000 * 0.31 \\ &= 0.009 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{CEE TIER 1 SSP}} &= (8500 * (1/10.9 - 1/11.8)) / 1000 * 0.31 \\ &= 0.018 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{ENERGY STAR PJM}} &= (8500 * (1/10.9 - 1/11.3)) / 1000 * 0.30 \\ &= 0.008 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{CEE TIER 1 PJM}} &= (8500 * (1/10.9 - 1/11.8)) / 1000 * 0.30 \\ &= 0.018 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

⁷⁰⁴ Consistent with coincidence factors found in:
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).

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Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$20.

Measure Life

The measure life is assumed to be 9 years.⁷⁰⁵

Operation and Maintenance Impacts

n/a

⁷⁰⁵ Based on Appliances Magazine - Market Research - The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013 (Dec. 2013).

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Retail Products

ENERGY STAR Soundbar

Unique Measure Code(s): RS_PL_TOS_RPPSND_0616
Effective Date: June 2016
End Date: TBD

Measure Description

This measure relates to the upstream promotion of residential soundbar meeting the ENERGY STAR criteria through the Energy Star Retail Products Program. This measure assumes a more stringent requirement than ENERGY STAR Version 3.0.⁷⁰⁶

Definition of Baseline Condition

The baseline condition is assumed to be a standard soundbar.

Definition of Efficient Condition

The RPP offers two tiers of incentives for this product – ENERGY STAR + 15% and ENERGY STAR +50% soundbar. Savings for both measures are given below. They were developed by decreasing the power requirements and increasing the efficiency requirements by the appropriate amount.

Annual Energy Savings Algorithm⁷⁰⁷

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

⁷⁰⁶<http://www.energystar.gov/sites/default/files/Final%20Version%203.0%20AV%20Program%20Requirements%20%28Rev%20Dec-2014%29.pdf>

⁷⁰⁷ Energy Savings from this measure are derived from Energy Star estimates. See ‘RPP Product Analysis 9-23-15.xlsx’

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Where:

kWh_{base}

kWh_{eff}

= Baseline unit energy consumption

= Assumed to be 69 kWh/year⁷⁰⁸

= Efficient unit energy consumption

= Assumed to be 25 kWh/year⁷⁰⁹ for the ENERGY STAR +50% Tier and 42.5 kWh/ year for the ENERGY STAR +15% Tier.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0.0005^{710}$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure is \$0⁷¹¹.

⁷⁰⁸ The baseline unit energy consumption is based on information provided from a Fraunhofer Center for Sustainable Energy System study, titled Energy Consumption of Consumer Electronics in US Households, 2013, available at: <http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf>.

⁷⁰⁹ Due to the high market penetration of ENERGY STAR certified soundbars, a weighted average of the unit energy consumption of both non-ENERGY STAR and ENERGY STAR models was calculated in order to accurately provide savings estimates for the market in 2016.

⁷¹⁰ Wattage difference between base and efficient sound bars when in sleep mode

⁷¹¹ Incremental cost comes from Energy Star characterization. See 'RPP Product Analysis 9-23-15.xlsx'

Measure Life

The expected measure life is assumed to be 7 years.⁷¹²

Operation and Maintenance Impacts

n/a

⁷¹² ENERGY STAR assumes a 7-year useful life.

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ENERGY STAR Air Cleaner

Unique Measure Code(s): RS_AP_TOS_RPPAPU_0616

Effective Date: June 2016

End Date: TBD

Measure Description

An air cleaner is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of a baseline model.

Definition of Baseline Condition

The baseline equipment is assumed to be a standard non-ENERGY STAR unit.

Definition of Efficient Condition

The efficient equipment is defined as an air cleaner meeting the efficiency specifications of ENERGY STAR as provided below⁷¹³.

- Clean Air Delivery Rate (CADR)/Watt Requirement: Must be equal to or greater than 2.0 CADR/Watt (Dust).
- UL Safety Requirements for Ozone Emitting Models: Measured ozone shall not exceed 50 parts per billion.
- Standby Power Requirements: Measured standby power shall not exceed 2 Watts.

⁷¹³https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%202.0%20Room%20Air%20Cleaners%20Specification%20%28Rev.%20May%202022%29_0.pdfhttp://www.energystar.gov/sites/default/files/specs//private/Room_Air_Cleaners_Final_V1.2_Specification.pdf

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Annual Energy Savings Algorithm

$$\Delta kWh^{714} = kWh_{Base} - kWh_{ESTAR}$$

Where:

kWh_{Base}

= Baseline kWh consumption per year
= see table below

kWh_{ESTAR}

= ENERGY STAR kWh consumption per year
= see table below

kWh_{Base}	kWh_{ESTAR}	kWh Savings
530.98	317.10	213.88

The retail products platform may also be used to incent air cleaners that are 30% and 50% better than energy star. In this case, the efficient consumption would be 222 kWh and 156 kWh, respectively.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/Hours * CF$$

⁷¹⁴ Baseline and ENERGY STAR energy consumptions are calculated by taking a weighted average of five product category sub types: 51-100 CADR, 101-150 CADR, 151-200 CADR, 201-250 CADR, and >250 CADR. Wattages for all five product sub types are derived from AHAM data. Duty cycle assumes 16 hours per day, 365 days per year based on filter replacement instructions.

Where:

ΔkWh	= Gross customer annual kWh savings for the measure
Hours	= Average hours of use per year
	= 5840 hours ⁷¹⁵
CF	= Summer Peak Coincidence Factor for measure
	= 0.67 ⁷¹⁶

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$0.⁷¹⁷

Measure Life

The measure life is assumed to be 9 years⁷¹⁸.

Operation and Maintenance Impacts

⁷¹⁵ Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.
⁷¹⁶ Assumes appliance use is equally likely at any hour of the day or night.
⁷¹⁷ ENERGY STAR Appliance Savings Calculator, which cites “EPA research on available models, 2012”
⁷¹⁸ ENERGY STAR assumption based on Lawrence Berkeley National Laboratory 2008 Status Report: Savings Estimates for the ENERGY STAR Voluntary Labeling Program, available at: [http://enduse.lbl.gov/Info/LBNL-56380\(2008\).pdf](http://enduse.lbl.gov/Info/LBNL-56380(2008).pdf)

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There are no operation and maintenance cost adjustments for this measure.⁷¹⁹

ENERGY STAR Desktop Computer

Unique Measure Code(s): RS_PL_TOS_RPPSDC_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the upstream promotion of desktop computers meeting the ENERGY STAR Computer Eligibility Criteria Version 6.1.

Definition of Baseline Condition

The baseline condition is assumed to be a standard desktop computer used in a residential setting.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR desktop computer meeting the current Eligibility Criteria Version 6.1 and used in a residential setting.⁷²⁰

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:

⁷¹⁹ Some types of room air cleaners require filter replacement or periodic cleaning, but this is likely to be true for both efficient and baseline units and so no difference in cost is assumed.
⁷²⁰<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Computers%20Version%208.0%20Final%20Specification%20Rev.%20July%202022.pdf>

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kWh_{base}

kWh_{eff}

= Baseline unit energy consumption

= Assumed to be 275 kWh/year⁷²¹

= Efficient unit energy consumption

= Assumed to be 156 kWh/year⁷²²

Summer Coincident Peak kW Savings Algorithm

ΔkWh

= $kWh_{base} - kWh_{eff} \times CF$

Where:

kWh_{base}

kWh_{eff}

CF

= Baseline unit wattage

= Assumed to be 48.11⁷²³

= Efficient unit wattage

= Assumed to be 27.11⁷²⁴

= 38%⁷²⁵

³Baseline kWh is derived from the ENERGY STAR Office Equipment Calculator October 2016. Set to residential use and default medium performance level.

⁴Efficient kWh is derived from the ENERGY STAR Office Equipment Calculator. October 2016. Set to residential use and default medium performance level.

⁷²³ Baseline wattage is for idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.

⁷²⁴ Efficient wattage is idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.

⁷²⁵ Average of two data sources. Efficiency Vermont. Technical Reference User Manual (TRM). March 16, 2015. Incremental cost of \$8 for an ENERGY STAR desktop computer with a compliant internal power supply. California Database of Energy Efficient Resources (DEER). Commercial desktop computer measure. Measure: WPSDGENROE0001-Rev01-Msr001-FULL. Incremental costof \$29.

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Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure is \$18.50.⁷²⁶

Measure Life

The expected measure life is assumed to be 4 years.⁷²⁷

Operation and Maintenance Impacts

n/a

⁷²⁶ ENERGY STAR Office Equipment Calculator.

⁷²⁷ ENERGY STAR Office Equipment Calculator.

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ENERGY STAR Laptop Computer

Unique Measure Code(s): RS_PL_TOS_RPPSLC_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the upstream promotion of laptop computers meeting the ENERGY STAR Computer Eligibility Criteria Version 6.1.

Definition of Baseline Condition

The baseline condition is assumed to be a standard laptop computer used in a residential setting.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR laptop computer meeting the current Eligibility Criteria Version 6.1 and used in a residential setting.⁷²⁸

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{base} - kWh_{eff}$

Where:

kWh_{base} = Baseline unit energy consumption

⁷²⁸<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Computers%20Version%208.0%20Final%20Specification%20Rev.%20July%202022.pdf>

kWh_{eff}

= Assumed to be 53 kWh/year⁷²⁹

= Efficient unit energy consumption

= Assumed to be 31 kWh/year⁷³⁰

Summer Coincident Peak kW Savings Algorithm

ΔkWh

= $kWh_{base} - kWh_{eff} \times CF$

Where:

kWh_{base}

= Baseline unit wattage

= Assumed to be 14.82⁷³¹

kWh_{eff}

= Efficient unit wattage

= Assumed to be 8.61⁷³²

CF

= 38%⁷³³

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

³Baseline kWh is derived from the ENERGY STAR Office Equipment Calculator October 2016. Set to residential use and default medium performance level.
⁴Efficient kWh is derived from the ENERGY STAR Office Equipment Calculator. October 2016. Set to residential use and default medium performance level.

⁷³¹ Baseline wattage is for idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.
⁷³² Efficient wattage is idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.
⁷³³ Estimate based on idle hours as a percentage of all hours.

n/a

Incremental Cost

The incremental cost for this time of sale measure is \$18.50.⁷³⁴

Measure Life

The expected measure life is assumed to be 4 years.⁷³⁵

Operation and Maintenance Impacts

n/a

⁷³⁴ Average of two data sources. Efficiency Vermont. Technical Reference User Manual (TRM). March 16, 2015. Incremental cost of \$8 for an ENERGY STAR desktop computer with a compliant internal power supply. California Database of Energy Efficient Resources (DEER). Commercial desktop computer measure. Measure: WPSDGENROE0001-Rev01-Msr001-FULL. Incremental cost of \$29..

⁷³⁵ ENERGY STAR Office Equipment Calculator.

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ENERGY STAR Computer Monitor

Unique Measure Code(s): RS_PL_TOS_RPPSCM_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the upstream promotion of monitors meeting the ENERGY STAR Display Eligibility Criteria Version [8.07.1](#).

Definition of Baseline Condition

The baseline condition is assumed to be a standard computer monitor used in a residential setting.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR computer monitor meeting the current Eligibility Criteria Version [8.06.1](#) and used in a residential setting.⁷³⁶

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{base} - kWh_{eff}$

Where:

kWh_{base} = Baseline unit energy consumption. If screen size is known:

Diagonal screen size	Conventional	ENERGY STAR

⁷³⁶<https://www.energystar.gov/sites/default/files/Displays%20Version%208.0%20Program%20Requirements%20Rev.%20Nov-2021.pdf>

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Less than 12 inches	16	11
12.0 - 16.9 inches	19	14
17.0 - 22.9 inches	33	26
23.0 - 24.9 inches	41	35
25.0 - 60.9 inches	65	49

Otherwise
= Assumed to be 41 kWh/year⁷³⁷
 kWh_{eff} = Efficient unit energy consumption. . If screen size is known, see above.

Otherwise:
= Assumed to be 35 kWh/year⁷³⁸

Summer Coincident Peak kW Savings Algorithm

ΔkWh = kWh_{base} – kWh_{eff} x CF

Where:
 kWh_{base} = Baseline unit wattage. If screen size is known:

Diagonal screen size	Conventional	ENERGY STAR
Less than 12 inches	6.6	5

³Baseline kWh is derived from the ENERGY STAR Office Equipment Calculator October 2016. Set to residential use and default to 23.0-24.9 diagonal screen size.
⁴Efficient kWh is derived from the ENERGY STAR Office Equipment Calculator. October 2016. Set to residential use and default to 23.0-24.9 diagonal screen size.

12.0 - 16.9 inches	8.2	5.8
17.0 - 22.9 inches	16.3	12.9
23.0 - 24.9 inches	20.3	17.2
25.0 - 60.9 inches	33.1	24.5

Otherwise

= Assumed to be 20.3.11⁷³⁹

kWh_{eff} = Efficient unit wattage

= Assumed to be 17.2⁷⁴⁰

CF = 22%⁷⁴¹

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure is \$2.⁷⁴²

Measure Life

⁷³⁹ Baseline wattage is for active power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default to 23.0-24.9 diagonal screen size.

⁷⁴⁰ Efficient wattage is active power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default to 23.0-24.9 diagonal screen size.

⁷⁴¹ Estimate based on active hours as a percentage of all hours.

⁷⁴² Efficiency Vermont. Technical Reference User Manual (TRM). March 16, 2015. Ultra Efficient LCD Monitor measure. Rounded up from stated incremental cost of \$1.80. .

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The expected measure life is assumed to be 7 years.⁷⁴³

Operation and Maintenance Impacts
n/a

⁷⁴³ ENERGY STAR Office Equipment Calculator.

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ENERGY STAR Television

Unique Measure Code(s): RS_PL_TOS_RPPSTV_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the upstream promotion of monitors meeting the ENERGY STAR Television Eligibility Criteria [Version 7.0](#).

Definition of Baseline Condition

The baseline condition is assumed to be a standard television used in a residential setting.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR television meeting the current Eligibility Criteria [Version 7.0](#) and used in a residential setting.⁷⁴⁴

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:

kWh_{base} = Baseline unit energy consumption varies by diagonal screen size.⁷⁴⁵

⁷⁴⁴ https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%209.0%20TVs%20Specification_0.pdf

⁷⁴⁵ ENERGY STAR Consumer Electronics Calculator. October 2016.

Diagonal screen size	Conventional	ENERGY STAR
20" and under	45	30
21" - 23"	48	39
24" - 29"	55	41
30" - 34"	66	49
35" - 39"	85	62
40" - 44"	101	71
45" - 49"	128	85
50" - 54"	137	97
55" - 59"	161	106
60" - 64"	162	122
65" or greater	295	137

kWh_{eff} = Efficient unit energy consumption varies by diagonal screen size.
See above.

Summer Coincident Peak kW Savings Algorithm

$\Delta kWh = kWh_{base} - kWh_{eff} \times CF$

Where:
kWh_{base} = Baseline unit wattage varies by diagonal screen size:

Diagonal screen size	Conventional	ENERGY STAR
20" and under	23	15

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21" - 23"	25	20
24" - 29"	29	21
30" - 34"	35	26
35" - 39"	46	33
40" - 44"	54	37
45" - 49"	69	45
50" - 54"	74	52
55" - 59"	87	57
60" - 64"	88	66
65" or greater	160	74

kWh_{eff} = Efficient unit wattage varies by diagonal screen size. See above.
 CF = 21%⁷⁴⁶

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this time of sale measure is \$0.⁷⁴⁷

⁷⁴⁶ Estimate based on On-mode hours per day (5 hours/day) as a percentage of all hours.
⁷⁴⁷ A zero incremental cost is supported by two sources. Efficiency Vermont. Technical Reference User Manual (TRM). March 16, 2015. Efficient Television measure has an incremental cost of \$0. The Appliance Standards Awareness Project assumes an incremental cost of \$0 for an appliance standard based on a prior version of the ENERGY STAR specification.
<https://appliance-standards.org/product/televisions>.

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Measure Life

The expected measure life is assumed to be 6 years.⁷⁴⁸

Operation and Maintenance Impacts

n/a

⁷⁴⁸ ENERGY STAR Consumer Electronics Calculator.

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COMMERCIAL & INDUSTRIAL MARKET SECTOR

Agricultural End Use

LED Exit Sign Engine Block Timer for Agricultural Equipment

Unique Measure Code(s): CI LT EREP LEDEXI 0518AG ENGTIMER
Effective Date: May 2018/July 2024
End Date: TBD

Measure Description

The measure is a plug-in timer that is activated below a specific outdoor temperature to control an engine block heater in agricultural equipment. Engine block heaters are typically used during cold weather to pre-warm an engine prior to start, for convenience, heaters are typically plugged in considerably longer than necessary to improve startup performance.

A timer allows a user to preset the heater to come on for only the amount of time necessary to pre-warm the engine block, reducing unnecessary run time even if the baseline equipment has an engine block temperature sensor. This measure relates to the installation of an exit sign illuminated with light emitting diodes (LED). This measure should be limited to early replacement applications.

Note: While this measure is characterized as an early replacement, a dual baseline is not used as it is assumed that the existing fixture would have been maintained with new baseline lamps (and ballasts, if required) for the duration of the measure life.

Definition of Baseline Condition

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The baseline scenario is an engine block heater that is manually plugged in by the farmer. The baseline condition is an existing exit sign with a non-LED light source.

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Definition of Efficient Condition

The efficient measure is an engine block heater operated by an outdoor plug-in timer (15 amp or greater) that turns on the heater only when the outdoor temperature is below 25 °F. The efficient condition is a new exit sign illuminated with light emitting diodes (LED).

Annual Energy Savings Algorithm

$$\Delta kWh = \frac{ISR * UseSeason * \%Days * HrSave/Day * kWheater - ParaId}{((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe}$$

Where:

$WattsBASEISR$ = Actual Connected load of existing exit sign In Service Rate. If connected load of existing exit sign is unknown, assume 78.39%16 W. 749750

$WattsEEUseSeason$ = Actual Connected load of LED exit sign Number of days in the use season in which the temperature is below 25°F 25

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⁷⁴⁹ Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015. Based on field study conducted by Efficiency Vermont on 352 sites in Vermont and Minnesota. 750

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Assumes a fluorescent illuminated exit sign. Wattage consistent with ENERGY STAR assumptions. See http://www.energystar.gov/ia/business/small_business/led-exitsigns-techsheet.pdf.

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$HOURS\% DAYS$ = Average hours of use per yearProportion of days timer is
used within the Use Season. If unknown, assume 84.23%⁷⁵¹

$HrSave/Day$ = Proportion of days timer is used within the Use SeasonHours of
savings per day when timer is used. If unknown, assume 7.765
hours per day⁷⁵²84.23%⁷⁵³

kW_{heater} = Connected load of the engine block heater
= 1.5 kW

ISR = In Service Rate or percentage of units rebated that get installed
= 1.00⁷⁵⁵

$WHFeParaLd$ = Waste Heat Factor for Energy to account for cooling and heating
impacts from efficient lighting-Parasitic Load
= 5.46 kWh⁷⁵⁶
= Varies by utility, building type, and HVAC equipment type. If
HVAC type is known, see table “Waste Heat Factors for C&I
Lighting — Known HVAC Types” in Appendix E. If HVAC type is

⁷⁵¹ EVT TRM, March 16, 2015. Based on field study conducted by EVT on 352 sites in Vermont and Minnesota.

⁷⁵² Ibid. The hours per day saved is sourced as the difference between the baseline run hours per day without the timer, 10.66 hours, and the efficient run hours per day with the timer, 2.90 hours.

⁷⁵³ EVT TRM, March 16, 2015. Based on field study conducted by EVT on 352 sites in Vermont and Minnesota.

⁷⁵⁴ Assumes operation 24 hours per day, 365 days per year.

⁷⁵⁵ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012–May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

⁷⁵⁶ Ibid.

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unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

n/a

$$\Delta kW = (WattsBASE - WattsEE) / 1000 * ISR * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting—Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

CF = Summer Peak Coincidence Factor for measure
= 1.0.⁷⁵⁷

Annual Fossil Fuel Savings Algorithm

n/a

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

AMMBTU = (- ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.
= (- ΔkWh / WHFe) * 0.00073.

⁷⁵⁷ Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

Where:

<u>0.7</u>	<u>= Aspect ratio</u> ⁷⁵⁸
<u>0.003413</u>	<u>= Constant to convert kWh to MMBTU</u>
<u>0.23</u>	<u>= Fraction of lighting heat that contributes to space heating</u> ⁷⁵⁹
<u>0.75</u>	<u>= Assumed heating system efficiency</u> ⁷⁶⁰

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost per installed plug-in timer is \$10.19.⁷⁶¹The lifecycle NPV incremental cost for this retrofit measure is \$35.⁷⁶²

Measure Life

⁷⁵⁸ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁷⁵⁹ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁷⁶⁰ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁷⁶¹ Based on bulk pricing reported by EnSave, which administers the rebate in Vermont.

⁷⁶² Represents the full installed cost of an LED exit sign. LED exit signs can typically be purchased for \$25 (see http://www.exitlightco.com/Exit_Signs and <http://www.simplyexitsigns.com/>). Assuming replacing exit sign requires 15 minutes of a common building laborer's time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately \$35.

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The expected measure life is assumed to be 3 years.⁷⁶³ The measure life is assumed to be 5 years.⁷⁶⁴

Operation and Maintenance Impacts

n/a

	Baseline
	CFL
Replacement Cost	\$8 ⁷⁶⁵
Component Life (years)	1.14 ⁷⁶⁶

The calculated net present value of the baseline replacement costs are presented below⁷⁶⁷:

⁷⁶³ Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.

⁷⁶⁴ To be ENERGY STAR-labeled, an LED exit sign must be guaranteed to last at least 5 years; however, many manufacturers state that their lamps will maintain National Fire Protection Association compliant levels of luminance for 10 to 25 years.

⁷⁶⁵ Represents the full installed cost of a replacement fluorescent lamp. Replacement lamps can typically be purchased for \$3.38 (based on 2017 Apex analysis). Assuming lamp replacement requires 15 minutes of a common building laborer's time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately \$8.

⁷⁶⁶ Assumes rated life of fluorescent replacement lamp is 10,000 hours. Assuming annual exit sign operating hours of 8,760, estimated lamp life is 1.14 years.

⁷⁶⁷ See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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<u>Baseline</u>	<u>NPV of Baseline Replacement Costs</u>
	<u>2017</u>
<u>CFL</u>	<u>\$26.92</u>

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Engine Block Timer for Agricultural EquipmentAuto Milker Takeoff

Unique Measure Code(s): CI AG ENGTIMERAUTOMILK
Effective Date: July 2024
End Date: TBD

Measure Description

This measure characterizes the energy savings for the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic Milker Takeoff measure reduces energy use by shutting off the milking vacuum pump suction once a minimum flowrate has been achieved.

Because automatic milker takeoffs have been standard equipment in new milk parlors since 1995, this measure is limited to existing dairy parlors for which no size upgrade or other vacuum system improvement has happened. The measure is a plug-in timer that is activated below a specific outdoor temperature to control an engine block heater in agricultural equipment. Engine block heaters are typically used during cold weather to pre-warm an engine prior to start, for convenience, heaters are typically plugged in considerably longer than necessary to improve startup performance.

A timer allows a user to preset the heater to come on for only the amount of time necessary to pre-warm the engine block, reducing unnecessary run time even if the baseline equipment has an engine block temperature sensor.

Definition of Baseline Condition

The baseline is an existing dairy parlor with no previously existing automatic milker takeoff and no plans to increase size and or make any other vacuum pump

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improvements. The baseline scenario is an engine block heater that is manually plugged in by the farmer.

Definition of Efficient Condition

The efficient measure is an engine block heater operated by an outdoor plug-in timer (15 amp or greater) that turns on the heater only when the outdoor temperature is below 25 °F. automatic milker takeoff installed on dairy milking vacuum pump systems.

Annual Energy Savings Algorithm

$$\Delta kWh = \frac{ISR * Use Season * \%Days * HrSave/Day * kWheater}{ParaLdkWh/cow/milking * Nmilings * Ncows}$$

Where:

kWh/cow/milking *ISR* = In Service Rate. Number of milkings per day. If unknown, assume 78.39%⁷⁶⁸ 50⁷⁶⁹

Use Season *Nmilings* = Number of days in the use season in which the temperature is below 25°F milkings per day. If unknown, assume 2⁷⁷⁰

⁷⁶⁸ Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015. Based on field study conducted by Efficiency Vermont on 352 sites in Vermont and Minnesota

⁷⁶⁹ Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006, and in agreement with IPL Energy Efficiency Programs 2009 Evaluation, KEMA. Appendix F Program Evaluations Group 1, Vol 2.,

⁷⁷⁰ Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives-Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy savings and the raw data used to generate load profiles showed, on average, two milkings per day. For further detail on the corroboration of this source, please see the 2016 Pennsylvania TRM.

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$\% \text{ DAYS Ncows}$ = Number of cows per farm. If unknown, assume 140⁷⁷¹ Proportion of days timer is used within the Use Season. If unknown, assume 84.23%⁷⁷²

HrSave/Day = Hours of savings per day when timer is used. If unknown, assume 7.765 hours per day⁷⁷³

$\text{kW}_{\text{heater}}$ = Connected load of the engine block heater
= 1.5 kW

ParaLd = Parasitic Load
= 5.46 kWh⁷⁷⁴

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kWh} = \Delta \text{kWh} * (1/\text{FLH}) * \text{CF}$$

Where:

FLH FLH = Full Load Hours. If unknown, Assume 2,703

CF = Coincidence Factor. If unknown, assume 0.793

n/a

⁷⁷¹ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140.

⁷⁷² EVT TRM, March 16, 2015. Based on field study conducted by EVT on 352 sites in Vermont and Minnesota.

⁷⁷³ Ibid. The hours per day saved is sourced as the difference between the baseline run hours per day without the timer, 10.66 hours, and the efficient run hours per day with the timer, 2.90 hours.

⁷⁷⁴ Ibid.

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Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

n/a

The incremental cost per installed plug-in timer is \$10.19.⁷⁷⁵

Measure Life

The expected measure life is assumed to be 103 years.⁷⁷⁶

Operation and Maintenance Impacts

n/a

⁷⁷⁵ Based on bulk pricing reported by EnSave, which administers the rebate in Vermont
⁷⁷⁶ Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.

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Scroll Compressor for Dairy Refrigeration

Unique Measure Code(s): CI AG AUTOMILKSCROLLCOMP
Effective Date: July 2024
End Date: TBD

Measure Description

Incorporating a more efficient compressor for process milk refrigeration can decrease the energy consumed at dairy farms. This measure is for the installation of a scroll compressor to replace an existing reciprocating compressor on a milk refrigeration bulk tank. The milk refrigeration system is used to cool milk for preservation and packaging. Milk is extracted from the cow at 98°F and cooled to 38°F, resulting in a substantial load on the milk cooling equipment, which is typically the largest energy use on a dairy farm. Scroll compressors can provide increased refrigeration efficiencies with improved EERs over baseline reciprocating compressors.

The energy savings for this measure are dependent on if the site is utilizing pre-cooling equipment such as a milk plate cooler. Plate coolers can reduce the incoming temperature of the milk into the refrigeration bulk tank, reducing the overall load on the compressor and the potential savings benefits. This measure characterizes the energy savings for the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic Milker Takeoff measure reduces energy use by shutting off the milking vacuum pump suction once a minimum flowrate has been achieved.

Because automatic milker takeoffs have been standard equipment in new milk parlors since 1995, this measure is limited to existing dairy parlors for which no size upgrade or other vacuum system improvement has happened.

Definition of Baseline Condition

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The baseline condition is assumed to be a reciprocating compressor, an existing dairy parlor with no previously existing automatic milker takeoff and no plans to increase size and or make any other vacuum pump improvements.

Definition of Efficient Condition

For an efficient scroll compressor with or without a plate cooler heat exchanger, the proposed compressor must be rated at 10.6 EER or greater on a process milk refrigeration system. The calculation assumes the cooling capacity of the compressor remains the same. The efficient measure is an automatic milker takeoff installed on dairy milking vacuum pump systems.

Annual Energy Savings Algorithm

$$\Delta kWh = kWh/cow/milking(1/EERbase - 1/EEReff) * Nmilkings Process Load * Ncows(1/1000)$$

Where:

$$\begin{aligned} kWh/cow/milkingEERbase &= \text{Efficiency of the existing compressor} \\ &= 8.4 \text{ Btu/watt}^{777} \\ EEReff &= \text{Efficiency of the installed compressor} \\ &= 10.6 \text{ Btu/watt}^{778} \end{aligned}$$

⁷⁷⁷ Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM - Plate Heat Exchanger and Well Water Pre-Cooler, 2017Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006, and in agreement with IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

⁷⁷⁸ Average efficiency of a scroll compressor, as sourced from Massachusetts Farm Energy: Best Management Practices for Dairy Farms, USDA NRCS, 2012 (page 33)Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM - Plate Heat Exchanger and Well Water Pre-Cooler, 2017.

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Lbs of Milk ~~EERbase~~ = The pounds of milk produced per day that needs to be cooled.
= 68 lbs of milk per cow⁷⁸⁵~~50⁷⁸⁶~~

Days ~~N~~milking = Number of milkings per day. If unknown, assume ~~2⁷⁸⁷~~365 Days per Year

Cows ~~N~~cows = Number of cows per farm. If unknown, assume 140⁷⁸⁸

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Summer Coincident Peak kW Savings Algorithm
 $\Delta \text{kWh} = \Delta \text{kWh} * (1/\text{FLH}) * \text{CF}$

Where:

785, "Ag Heat Recovery Tank Supplemental Data." WI Dairy Statistics tab shows USDA reported annual data from: U.S. Department of Agriculture. "Milk Production per Cow, Wisconsin."

786 Alliant's Global Energy Partners impact calculations in DSM Tracking, 2006, and in agreement with IPL Energy Efficiency Programs 2009 Evaluation, KEMA, Appendix F Program Evaluations Group 1, Vol 2.

787 Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy savings and the raw data used to generate load profiles showed, on average, two milkings per day. For further detail on the corroboration of this source, please see the 2016 Pennsylvania TRM.

788 Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140.

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FLH = Full Load Hours. If unknown, Assume 2,703⁷⁸⁹

CF = Coincidence Factor. If unknown, assume 0.79⁷⁹⁰

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The expected incremental measure cost is assumed to be \$447 per compressor.⁷⁹¹

n/a

Measure Life

The expected measure life is assumed to be 150 years.⁷⁹²

⁷⁸⁹ Raw milk for pasturing must be cooled with 4 hours. Assuming 2 milking per day. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.

⁷⁹⁰ Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015

⁷⁹¹ The incremental cost is sourced from the PG&E Workpaper - Scroll Compressor (PGE3PAGR113), February 2013. The incremental cost is based on the difference in material and labor cost between a reciprocating compressor, \$2,538, and a scroll compressor, \$2,985.

⁷⁹² Focus on Energy Evaluation Business Programs Measure Life Study: Final Report August 25, 2009, Public Service Commission of Wisconsin.

Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.

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Operation and Maintenance Impacts
n/a

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Dairy Refrigeration Heat Recovery

Unique Measure Code(s): CI AG AUTOMILKHEATRECOV
Effective Date: July 2024
End Date: TBD

Measure Description

A refrigeration heat recovery (RHR) unit captures waste heat from the refrigeration system and uses a heat exchange to transfer some of that heat into incoming well water. That captured waste heat is used to pre-heat ground water before it enters the primary water heater and brought to the desired final temperature needed for cleaning farm equipment. The hot compressed refrigerant is diverted and flows through the heat exchanger, attached to a secondary water tank, on its way to the condenser unit. The heat from the refrigerant is transferred through the tank into the water. Thermal buoyancy causes the warmest water to rise to the top of the tank. When hot water is used, water flows from the RHR tank into the water heater, and well water flows into the heat recovery tank. These units can assist in reducing water heating energy use by approximately 50%.

It is important to note that if a dairy farm installs an RHR unit and a milk plate cooler, (with or without the use of milk pump VFD control), the plate cooler will impact the savings potential of the RHR unit. The use of a plate cooler will reduce the total milk mechanical refrigeration load. Due to this refrigeration load reduction, the amount of heat rejection possible to the RHR system is diminished. Incorporating a more efficient compressor for process milk refrigeration can decrease the energy consumed at dairy farms. This measure is for the installation of a scroll compressor to replace an existing reciprocating compressor on a milk refrigeration bulk tank. The milk refrigeration system is used to cool milk for preservation and packaging. Milk is extracted from the cow at 98°F and cooled to 38°F, resulting in a substantial load on the milk cooling

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equipment, which is typically the largest energy use on a dairy farm. Scroll compressors can provide increased refrigeration efficiencies with improved EERs over baseline reciprocating compressors.

The energy savings for this measure are dependent on if the site is utilizing pre-cooling equipment such as a milk plate cooler. Plate coolers can reduce the incoming temperature of the milk into the refrigeration bulk tank, reducing the overall load on the compressor and the potential savings benefits.

Definition of Baseline Condition

The baseline condition is an existing dairy farm with refrigeration equipment and a water heater unit without the use of an RHR unit to feed preheated water to the water heater. Water heater is fed directly with ground water. The baseline condition is assumed to be a reciprocating compressor.

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Definition of Efficient Condition

The efficient condition is farm refrigeration equipment where an RHR tank is installed and captures waste refrigerant heat from the refrigeration system compressor and transfers that waste into an RHR tank, supplied with cool ground water, through a heat exchanger before continuing through the refrigeration system condensing unit. The newly preheated water in the RHR tank is supplied into the farm's main water heater unit, which will have a smaller temperature differential to overcome, compared to a direct ground water heater feed. For an efficient scroll compressor with or without a plate cooler heat exchanger, the proposed compressor must be rated at 10.6 EER or greater on a process milk refrigeration system. The calculation assumes the cooling capacity of the compressor remains the same.

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Annual Energy Savings Algorithm

$$\Delta kWh = \frac{Btu_{Recovered} (1/EER_{base} - 1/EER_{eff}) * Process Load Days * (1/1000 E_{elec})}{* (1/3,412)}$$

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Where:

$$EER_{base} Btu_{Recovered} = \frac{Btu_{Recovered}}{Storage \text{ (lesser of the two)}} = \frac{Btu_{Milk Potential or Btu_{RHR}}}{Efficiency of the existing compressor}$$

$$= 8.4 Btu/watt^{793}$$

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$$EER_{eff} Btu_{Milk Potential} = \frac{Lbs \text{ of Milk} \times Cows \times CP_{Milk} \times \Delta T_{Milk} \times SF}{Efficiency of the installed compressor}$$

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$$And$$

$$Btu_{Storage} = \frac{Hot Water \times CP_{Water} \times P_{Water} \times \Delta T_{Water}}{}$$

Where:

$$Days = 365 Days$$

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⁷⁹³ Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM—Plate Heat Exchanger and Well Water Pre-Cooler, 2017

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$\frac{\text{Days}3,412}{365 \text{ Days}}$ = $\frac{\text{Btu to kWh electric conversion factor}}{365 \text{ Days}}$

$\frac{\text{Days}EF_{elec}}{90\%}$ = $\frac{\text{Energy factor for a standard electric water heater}}{365 \text{ Days}}$

$C_{P,Milk}$ = Specific Heat of Milk
= 0.93 Btu/lb °F⁷⁹⁴

$C_{P,Water}$ = Specific Heat of Water
= 1.0 Btu/lb °F⁷⁹⁵

ΔT_{milk} = Change in Milk Temperature
= °F_{initial} - °F_{final}⁷⁹⁶

T_{milk} = Temperature of milk being supplied that needs to be cooled

_____ = 98°F if no pre-cooler is used in operation;

_____ = 68°F if a milk pre-cooler is used;

_____ = 56.3°F if a milk pre-cooler and VFD milk transfer pump are used.

_____ = 60°F without a plate cooler⁷⁹⁶

794 Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration, Page 19.5.

795 Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration, Page 19.5.

796 Safe Handling of Milk & Dairy Products, March 8th, 2017 and Sanford, Scott (University of Wisconsin-Madison). "Well Water Precoolers." Publication A37843, October 2003. The temperature of the milk exiting the cow is considered to be 98°F and the final, cooled temperature of the milk is assumed to be 38°F.

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T_{in} = Final stored temperature of cooled milk
= 38°F

= 68°F if a milk pre-cooler is used;
= 56.3°F if a milk pre-cooler and VFD milk transfer pump are used.

= 30°F with a plate cooler⁷⁹⁷

$Lbs\ of\ Milk\ SF$ = Savings factor for the percentage of energy able to be captured from the milk cooling process The pounds of milk produced per day that needs to be cooled.
= 68 lbs of milk per cow⁷⁹⁸

$Days\ Hot\ Water$ = Amount of hot water per day in gallons that the site uses for washing and cleaning purposes

797 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 of milk temperature difference for a single pass plate cooler and a 35°F of temperature difference for a double/multi-pass plate cooler. For the purposes of this measure, a straight average of 30°F between the two types was used. A plate cooler reduces the overall load on the refrigeration compressors and the revised ΔT when accounting for a milk pre-cooler is 30°F less.

798 DeLaval. "Dairy Farm Energy Efficiency." April 20, 2011. DeLaval estimates the heat recovery potential to be between 20 and 60%. Based on engineering judgement and further corroboration from the Wisconsin Focus on Energy TRM, opted to default to a 55% savings factor. "Ag Heat Recovery Tank Supplemental Data." WI Dairy Statistics tab shows USDA reported annual data from: U.S. Department of Agriculture. "Milk Production per Cow, Wisconsin."

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$= 131.7 \text{ gallons}^{799} \times 365 \text{ Days per Year}$

Cows $= \text{Number of cows per farm. If unknown, assume } 140^{800}$

$P_{\text{water}} = 8.34 \text{ lb/gal water} \times \text{Days} \times \text{Lbs of Milk} = \text{The pounds of milk produced per day per cow that needs to be cooled}$ 365 Days

$\Delta T_{\text{water}} = \text{Change in Water Temperature}$

$= ^\circ F_{\text{warm water}} - ^\circ F_{\text{FINAL cold water}}$

$^\circ F_{\text{warm water}} = \text{Temperature of milk being supplied that needs to be cooled}$

$= 98^\circ F \text{ if no pre-cooler is used in operation } 120^\circ F, \text{ expected temperature a refrigeration heat recovery unit can pre-heat well water up to } 120;$

⁷⁹⁹ The hot water use per day is based on the average hot water requirements per wash cycle multiplied by the number of wash cycles per day. The average amount of hot water used per wash cycle, 47.9 gallons, is sourced from the National Resource Conservation Service for Wash Water Requirements for Milking Systems, a calculator developed by University of Wisconsin, August 2005, Milking Center Waste Volume, v12.05. The number of wash cycles per day account for the hot water rinse cycles that are used to flush and clean the milk lines before and after milking. As sourced from the Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List; Agricultural: Variable Frequency Drives-Dairy, FY2012, v1.2. Pre- and post-power meter data for five sites were used to establish RTF energy savings and the raw data used to generate load profiles showed, on average, two milkings per day. As there will be one more wash cycle than milking, the default average wash cycles per day is three.

⁸⁰⁰ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140

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$C_{p, \text{Milk}}$ = Specific Heat of Milk

⁸⁰² [Average efficiency of a scroll compressor, as sourced from Massachusetts Farm Energy: Best Management Practices for Dairy Farms, USDA NRCS, 2012 \(page 33\).](#)

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	<u>= 0.93 Btu/lb °F⁸⁰³</u>
<u>ΔT</u>	<u>= Efficiency of the installed compressor</u> <u>= 60°F without a plate cooler⁸⁰⁴</u> <u>= 30°F with a plate cooler⁸⁰⁵</u>
<u>Lbs of Milk</u>	<u>= The pounds of milk produced per day that needs to be cooled.</u> <u>= 68 lbs of milk per cow⁸⁰⁶</u>
<u>Days</u>	<u>= 365 Days per Year</u>
<u>Cows</u>	<u>= Number of cows per farm. If unknown, assume 140⁸⁰⁷</u>

⁸⁰³ Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook – Refrigeration, Page 19.5.

⁸⁰⁴ Safe Handling of Milk & Dairy Products, March 8th, 2017 and Sanford, Scott (University of Wisconsin-Madison), “Well Water Precoolers,” Publication A37843, October 2003. The temperature of the milk exiting the cow is considered to be 98°F and the final, cooled temperature of the milk is assumed to be 38°F.

⁸⁰⁵ 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 of milk temperature difference for a single pass plate cooler and a 35°F of temperature difference for a double/multi-pass plate cooler. For the purposes of this measure, a straight average of 30°F between the two types was used. A plate cooler reduces the overall load on the refrigeration compressors and the revised ΔT when accounting for a milk pre-cooler is 30°F less.

⁸⁰⁶ “Ag Heat Recovery Tank Supplemental Data.” WI Dairy Statistics tab shows USDA reported annual data from: U.S. Department of Agriculture, “Milk Production per Cow, Wisconsin.”

⁸⁰⁷ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397. Average number of cows per farm = 223,579 cows / 1,592 farms = 140.

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Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kWh} = \Delta \text{kWh} * (1/\text{FLH}) * \text{CF}$$

Where:

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FLH = Full Load Hours. If unknown, Assume 2,920⁸⁰⁸

CF = Coincidence Factor. If unknown, assume 0.34⁸⁰⁹

Annual Fossil Fuel Savings Algorithm

Other variables remain consistent with ‘Electric Energy Savings’ calculation method

Where:

FLH100,000 = Full Load Hours. If unknown, Assume 2,920⁸¹⁰Btu to therms natural gas conversion factor

CFEF_{gas} = Coincidence Factor. If unknown, assume 0.34⁸¹¹ Energy Factor for standard natural gas water heater

= 59%

n/a

Annual Water Savings Algorithm

n/a

⁸⁰⁸ Raw milk for pasturing must be cooled with 4 hours. Assuming 2 milking per day. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.

⁸⁰⁹ Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015

⁸¹⁰ Raw milk for pasturing must be cooled with 4 hours. Assuming 2 milking per day. Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.

⁸¹¹ Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015

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Incremental Cost

The expected incremental measure cost is assumed to be \$4,35347 per compressor.⁸¹²

Measure Life

The expected measure life is assumed to be 15 years.⁸¹³

Operation and Maintenance Impacts

n/a

812 The incremental cost is sourced from Efficiency Vermont custom project data based on actual equipment installs between 2010 and 2017. The incremental cost is sourced from the PG&E Workpaper—Scroll Compressor (PGE3PAGR113), February 2013. The incremental cost is based on the difference in material and labor cost between a reciprocating compressor, \$2,538, and a scroll compressor, \$2,985.
813 PA Consulting Group Inc. “State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Measure Life Study Final Report.” August 25, 2009. Focus on Energy Evaluation Business Programs Measure Life Study: Final Report August 25, 2009, Public Service Commission of Wisconsin.

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Livestock Waterer

Unique Measure Code(s): CI AG WATERER

Effective Date: July 2024

End Date: TBD

Measure Description

¶This measure applies to the replacement of electric open waterers with sinking or floating water heaters with equivalent herd size watering capacity of the old unit. Livestock waterers utilize electric heating elements and are used in cold climate locations in order to prevent water from freezing. Energy efficient livestock waterers, also called no or low energy livestock waterers, are closed and insulated watering containers that use lower wattage heating elements, thermostatically controlled, and water agitation (either in the form of air bubbles or floating balls), to prevent water from freezing, using less energy. Incorporating a more efficient compressor for process milk refrigeration can decrease the energy consumed at dairy farms. This measure is for the installation of a scroll compressor to replace an existing reciprocating compressor on a milk refrigeration bulk tank. The milk refrigeration system is used to cool milk for preservation and packaging. Milk is extracted from the cow at 98°F and cooled to 38°F, resulting in a substantial load on the milk cooling equipment, which is typically the largest energy use on a dairy farm. Scroll compressors can provide increased refrigeration efficiencies with improved EERs over baseline reciprocating compressors.

The energy savings for this measure are dependent on if the site is utilizing pre-cooling equipment such as a milk plate cooler. Plate coolers can reduce the incoming temperature of the milk into the refrigeration bulk tank, reducing the overall load on the compressor and the potential savings benefits.

Definition of Baseline Condition

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The baseline condition is assumed to be a reciprocating compressor-assumed to be an electric open waterer with sinking or floating water heaters that have reached the end of useful life.

Definition of Efficient Condition

The efficient equipment is assumed to an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on unit with heating element greater than or equal to 250 watts. For an efficient scroll compressor with or without a plate cooler heat exchanger, the proposed compressor must be rated at 10.6 EER or greater on a process milk refrigeration system. The calculation assumes the cooling capacity of the compressor remains the same.

Annual Energy Savings Algorithm

The annual electric savings from this measure is a deemed value and assumed to be 1,592.85 kWh⁸¹⁴. $\Delta kWh = (1/EER_{base} - 1/EER_{eff}) * Process Load * (1/1000)$

Where:

EER_{base} = Efficiency of the existing compressor
= 8.4 Btu/watt⁸¹⁵

EER_{eff} = Efficiency of the installed compressor
= 10.6 Btu/watt⁸¹⁶

⁸¹⁴ 2024 IL TRM

⁸¹⁵ Average efficiency of a reciprocating compressor, as sourced from Wisconsin Focus on Energy TRM—Plate Heat Exchanger and Well Water Pre-Cooler, 2017

⁸¹⁶ Average efficiency of a scroll compressor, as sourced from Massachusetts Farm Energy: Best Management Practices for Dairy Farms, USDA NRCS, 2012 (page 33)

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$$\text{Process Load} = C_{p, \text{Milk}} \times \Delta T \times \text{Lbs of Milk} \times \text{Cows} \times \text{Days}$$

Where:

$$C_{p, \text{Milk}} = \text{Specific Heat of Milk} \\ = 0.93 \text{ Btu/lb}^\circ\text{F}^{817}$$

$$\Delta T = \text{Efficiency of the installed compressor} \\ = 60^\circ\text{F without a plate cooler}^{818} \\ = 30^\circ\text{F with a plate cooler}^{819}$$

$$\text{Lbs of Milk} = \text{The pounds of milk produced per day that needs to be cooled.} \\ = 68 \text{ lbs of milk per cow}^{820}$$

$$\text{Days} = 365 \text{ Days per Year}$$

⁸¹⁷ Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration, Page 19.5.

⁸¹⁸ Safe Handling of Milk & Dairy Products, March 8th, 2017 and Sanford, Scott (University of Wisconsin-Madison). "Well Water Precoolers." Publication A37843, October 2003. The temperature of the milk exiting the cow is considered to be 98°F and the final, cooled temperature of the milk is assumed to be 38°F.

⁸¹⁹ 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 of milk temperature difference for a single pass plate cooler and a 35°F of temperature difference for a double/multi-pass plate cooler. For the purposes of this measure, a straight average of 30°F between the two types was used. A plate cooler reduces the overall load on the refrigeration compressors and the revised ΔT when accounting for a milk pre-cooler is 30°F less.

⁸²⁰ "Ag Heat Recovery Tank Supplemental Data." WI Dairy Statistics tab shows USDA reported annual data from: U.S.

Department of Agriculture. "Milk Production per Cow, Wisconsin."

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Cows = Number of cows per farm. If unknown, assume 140⁸²¹

Summer Coincident Peak kW Savings Algorithm

n/a $\Delta kW_h = \Delta kW_h * (1/FLH) * CF$

Where:

FLH = Full Load Hours. If unknown, Assume 2,920⁸²²

CF = Coincidence Factor. If unknown, assume 0.34⁸²³

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

⁸²¹ Entered from application form; default value is sourced from the 2017 U.S. Census of Agriculture, Iowa State Summary Highlights, Full Report, Volume 1, Chapter 2, U.S. State Level, 397, Average number of cows per farm = 223,579 cows / 1,592 farms = 140

⁸²² Raw milk for pasturing must be cooled with 4 hours. Assuming 2 milking per day, Dairy Farm Energy Management Guide: California, Ludington, Johnson, Kowalski, & Mage, Southern California Edison, 2004.

⁸²³ Efficiency Vermont (EVT) Technical Reference Manual (TRM), Measure Savings Algorithms and Cost Assumptions, March 16, 2015

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The expected incremental measure cost is assumed to be \$787.50447 per compressor.⁸²⁴

Measure Life

The expected measure life is assumed to be 105 years.⁸²⁵

Operation and Maintenance Impacts

n/a

824 The incremental cost is sourced from the PG&E Workpaper – Scroll Compressor (PGE3PAGR113), February 2013. The incremental cost is based on the difference in material and labor cost between a reciprocating compressor, \$2,538, and a scroll compressor, \$2,985. Ibid

825 Ibid Focus on Energy Evaluation Business Programs Measure Life Study: Final Report August 25, 2009, Public Service Commission of Wisconsin.

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VSD Milk Pump with Plate Cooler Heat Exchanger

Unique Measure Code(s): CI AG WATERERVSD MILK HX
Effective Date: July 2024
End Date: TBD

Measure Description

This technology incorporates adding a variable speed drive to a milk transfer pump. The VSD drive reduces the heat transferred to milk during pumping operation as well increases the amount of time the milk is in the free cooling heat exchanger. The VFD regulates the milk pump in order to increase the efficacy of the plate cooler heat exchanger by slowing the flow of milk. This results in a maximum heat transfer between the warm milk and the cold water used in the plate cooler.

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Energy savings are realized by the reduced load on the primary milk cooling system. A milk transfer pump VSD is only effective if paired with a plate cooler. This measure applies to the replacement of electric open waterers with sinking or floating water heaters with equivalent herd size watering capacity of the old unit. Livestock waterers utilize electric heating elements and are used in cold climate locations in order to prevent water from freezing. Energy efficient livestock waterers, also called no or low energy livestock waterers, are closed and insulated watering containers that use lower wattage heating elements, thermostatically controlled, and water agitation (either in the form of air bubbles or floating balls), to prevent water from freezing, using less energy.

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Definition of Baseline Condition

The baseline condition must have a constant speed milk transfer process pump with no existing VSD controls. A plate cooling heat exchanger can already be a part of the system, or one installed in concert with the VSD. is assumed to be be an electric

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~~open waterer with sinking or floating water heaters that have reached the end of useful life.~~

Definition of Efficient Condition

~~The efficient equipment is the installation of a new variable speed drive (VSD) on a new or existing milk transfer process pump. is assumed to an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on unit with heating element greater than or equal to 250 watts.~~

Annual Energy Savings Algorithm

~~The annual electric savings from this measure is a deemed value and assumed to be 1,592.85 kWh⁸²⁶.~~

Summer Coincident Peak kW Savings Algorithm

~~n/a~~

Annual Fossil Fuel Savings Algorithm

~~n/a~~

Annual Water Savings Algorithm

~~n/a~~

Incremental Cost

~~The~~ The average equipment cost of a milk vacuum pump variable speed drive is \$3,871 with an installation cost of \$1,177, for a total incremental measure of

⁸²⁶ 2024 IL TRM

\$5,048.43⁸²⁷ expected incremental measure cost is assumed to be \$787.50 per compressor.⁸²⁸

Measure Life
The expected measure life is assumed to be 10 years.⁸²⁹

Operation and Maintenance Impacts
n/a

⁸²⁷ The equipment and labor costs are sourced from the PG&E Workpaper - Milk Vacuum Pump VSD, Dairy Farm Equipment (PGE3PAGR116), February 2013.
⁸²⁸ Ibid
⁸²⁹ Ibid

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Low Pressure Irrigation Sprinkler Nozzles

Unique Measure Code(s): CI AG LOW IRRIGATION
Effective Date: July 2024
End Date: TBD

Measure Description

Incorporating low pressure sprinkler nozzles can decrease the energy and water consumed by reducing required water supply pressure to irrigate crop fields. Low pressure sprinkler nozzles can provide uniform water application by using various orifice applications and configurations while operating at a lower pressure compared to standard, impact driven sprinkler heads. Energy savings are achieved by the irrigation system operating at a lower water pressure while maintaining the same water distribution. This technology incorporates adding a variable speed drive to a milk transfer pump. The VSD drive reduces the heat transferred to milk during pumping operation as well increases the amount of time the milk is in the free cooling heat exchanger. The VFD regulates the milk pump in order to increase the efficacy of the plate cooler heat exchanger by slowing the flow of milk. This results in a maximum heat transfer between the warm milk and the cold water used in the plate cooler.

Energy savings are realized by the reduced load on the primary milk cooling system. A milk transfer pump VSD is only effective if paired with a plate cooler.

Definition of Baseline Condition

The baseline condition applies to the replacement of high pressure irrigation nozzles that operate at 50 psi or greater at rated/required flow. must have a constant speed milk transfer process pump with no existing VSD controls. A plate cooling heat exchanger can already be a part of the system, or one installed in concert with the VSD.

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Definition of Efficient Condition

The Low-Pressure Irrigation Nozzles operate at 35 psi or lower at rated/required flow. Annual Electric Savings obtained will be based on the number of nozzles replaced. To qualify the nozzles must operate for more than 500 hours per year and provide the equivalent flow at the reduced pressure. The maximum pump pressure must also be reduced accordingly. efficient equipment is the installation of a new variable speed drive (VSD) on a new or existing milk transfer process pump.

Annual Energy Savings Algorithm

The annual energy savings and coincidental electric demand savings is based on PG&E research on irrigation well pumping systems and corrected based upon the type of crop, irrigated acres, and average acre-feet of water applied per acre⁸³⁰.

The annual electric savings from this measure is a deemed value and assumed to be 4.06 kWh/yr/nozzle1,592.85 kWh⁸³¹.

Summer Coincident Peak kW Savings Algorithm

Annual kW Savings = 0.0017 kW/yr/nozzle n/a

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

⁸³⁰ For additional detail on the derivation of Illinois-specific savings values and how the original source material was modified and normalized into single deemed values, please see the Illinois Workpaper for this measure.

⁸³¹ 2024 IL TRM

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n/a

Incremental Cost

The average equipment cost of a milk vacuum pump variable speed drive is \$3,871 with an installation cost of \$1,177, for a total incremental measure of \$5,048., including labor, is \$1.74 per nozzle.⁸³²~~43~~⁸³³

Measure Life

The expected measure life is assumed to be 510 years.⁸³⁴

Operation and Maintenance Impacts

n/a

⁸³² The incremental cost is sourced from SCE Workpaper, SCE13WP007, Low pressure Sprinkler Nozzles, January 2013.

⁸³³ The equipment and labor costs are sourced from the PG&E Workpaper—Milk Vacuum Pump VSD, Dairy Farm Equipment (PGE3PAGR116), February 2013.

⁸³⁴ Ibid

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Dairy Refrigeration Tune-Up

Unique Measure Code(s): CI AG DAIRY TUNEUP
Effective Date: July 2024
End Date: TBD

Measure Description

The efficient condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The Service Provider must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks: clean and inspect condenser and evaporator coils; clean drain pan; inspect/clean fans, screens, grills, filters, and drier cores; inspect/adjust heat reclaim operation; tighten all line voltage connections; inspect/replace relays and capacitors as needed; and add/remove refrigerant charge as needed. ~~Incorporating low pressure sprinkler nozzles can decrease the energy and water consumed by reducing required water supply pressure to irrigate crop fields. Low pressure sprinkler nozzles can provide uniform water application by using various orifice applications and configurations while operating at a lower pressure compared to standard, impact driven sprinkler heads. Energy savings are achieved by the irrigation system operating at a lower water pressure while maintaining the same water distribution.~~

Definition of Baseline Condition

The baseline condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has not been inspected or tuned up in more than 12 months. ~~The baseline condition applies to the replacement of high pressure irrigation nozzles that operate at 50 psi or greater at rated/required flow.~~

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Definition of Efficient Condition

~~The~~This tune-up is designed to assess all refrigeration equipment associated with a commercial-grade dairy farm facility with the intention of reducing electrical consumption. ~~Low-Pressure Irrigation Nozzles operate at 35 psi or lower at rated/required flow. Annual Electric Savings obtained will be based on the number of nozzles replaced. To qualify the nozzles must operate for more than 500 hours per year and provide the equivalent flow at the reduced pressure. The maximum pump pressure must also be reduced accordingly.~~

Annual Energy Savings Algorithm

~~The Energy savings from the refrigeration equipment tune up/maintenance is 5%⁸³⁵. annual energy savings and coincidental electric demand savings is based on PG&E research on irrigation well pumping systems and corrected based upon the type of crop, irrigated acres, and average acre feet of water applied per acre⁸³⁶.~~

⁸³⁵ “Dairy Refrigeration Tune-up, Agriculture Potential Study Data.” Spreadsheet. Potential Study Survey Data tab shows the breakdown of Wisconsin dairy farms with existing milking equipment scenarios based on 2017 Wisconsin Focus on Energy Potential Study results. Compressor Modeling tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compress. Pre-cooler Measure Analysis tab showing sample data of 86 pre-cooler projects entered in Spectrum from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects.

⁸³⁶ For additional detail on the derivation of Illinois-specific savings values and how the original source material was modified and normalized into single deemed values, please see the Illinois Workpaper for this measure.

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$$kWh_{SAVED} = kWh_{SAVED} / day * 365 \text{ dDays}$$

$$kWh_{SAVED}/day = [lbs \text{ milk}/day * CP_{,MILK} * (^{\circ}FIN - ^{\circ}FFINAL) / AEER \text{ COMPRESSOR} / 1,000] * SF$$

Where:

365 Days = Number of days per year cows are milked. Assume 365 if unknown.⁵

$lbs \text{ milk}/day$ = Pounds of milk produced at farm facility per day (= 68 pounds of milk per cow); ~~3.5 the number of milking cows is a user-defined input~~

$CP_{,Milk}$ = Specific Heat of Milk
= 0.93 Btu/lb °F⁸³⁷

ΔT_{milk} = Change in Milk Temperature
= °F_{in} - °F_{final}

$^{\circ}F_{in}$ = Temperature of milk being supplied that needs to be cooled
= 98°F if no pre-cooler is used in operation;
= 68°F if a milk pre-cooler is used;
= 56.3°F if a milk pre-cooler and VFD milk transfer pump are used.
 $^{\circ}F_{in}$ = Final stored temperature of cooled milk
= 38°F

⁸³⁷ Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration. Page 19.5.

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SF = Savings factor for the percentage of energy able to be captured from the tune up process
= 5%

C_{P, MILK} = Specific heat of milk (= 0.94 Btu/lb-°F) 6

°FIN = Temperature of supplied milk that needs to be mechanically cooled (= 71.8°F, or = 98°F if no pre-cooler used in operation; 7 = 67°F if a milk pre-cooler unit is used; = 56.3°F if a milk pre-cooler unit and VFD milk pump are used; see Assumptions)

°FFINAL = Final stored temperature of cooled milk (= 38°F) 7

AEER COMPRESSOR = Annual energy efficiency ratio of refrigeration compressor (= 15.39 Btu/watt-hour; 4 see Assumptions)

1,000 = Kilowatt conversion factor

SF = Energy savings factor (= 0.05) 4The annual electric savings from this measure is a deemed value and assumed to be 4.06 kWh/yr/nozzle⁸³⁸.

Summer Coincident Peak kW Savings Algorithm

n/a

Annual kW Savings = 0.0017 kW/yr/nozzle

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

n/a

⁸³⁸ 2024 IL TRM

The average equipment cost, including labor, is \$1.74 per nozzle.⁸³⁹

Measure Life

The expected measure life is assumed to be 51 years as standard for tune up measures.

Operation and Maintenance Impacts

n/a

⁸³⁹ The incremental cost is sourced from SCE Workpaper, SCE13WP007, Low pressure Sprinkler Nozzles, January 2013.

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High Speed Fans

Unique Measure Code(s): CI AG HS FAN
Effective Date: July 2024
End Date: TBD

Measure Description

~~The~~ This measure applies to high speed exhaust, ventilation and circulation fans that are replacing an existing unit that reached the end of its useful life in agricultural applications.
~~efficient condition is refrigeration equipment associated with a commercial grade dairy farm facility that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The Service Provider must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks: clean and inspect condenser and evaporator coils; clean drain pan; inspect/clean fans, screens, grills, filters, and drier cores; inspect/adjust heat reclaim operation; tighten all line voltage connections; inspect/replace relays and capacitors as needed; and add/remove refrigerant charge as needed.~~

Definition of Baseline Condition

~~In order for this characterization to apply, the baseline condition is assumed to be an existing fan that reached the end of its useful life. The baseline condition is refrigeration equipment associated with a commercial grade dairy farm facility that has not been inspected or tuned up in more than 12 months.~~

Definition of Efficient Condition

~~This~~~~In tune up~~ In order for this characterization to apply, the efficient equipment is assumed to be diffuser equipped and meet the following minimum efficiency criteria.~~is~~

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designed to assess all refrigeration equipment associated with a commercial grade dairy farm facility with the intention of reducing electrical consumption.

<u>Diameter of Fan (inches)</u>	<u>Minimum Efficiency for Exhaust & Ventilation Fans</u>	<u>Minimum Efficiency for Circulation Fans</u>
<u>24 through 35</u>	<u>14.0 cfm/W at 0.10 static pressure</u>	<u>12.5 lbf/kW</u>
<u>36 through 47</u>	<u>17.1 cfm/W at 0.10 static pressure</u>	<u>18.2 lbf/kW</u>
<u>48 through 71</u>	<u>20.3 cfm/W at 0.10 static pressure</u>	<u>23.0 lbf/kW</u>

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Annual Energy Savings Algorithm

The energy savings for this measure are deemed values depending on fan size, and size and apply to all building types per the below table.

<u>Diameter of Fan (inches)</u>	<u>kWh</u>
<u>24 through 35</u>	<u>372</u>
<u>36 through 47</u>	<u>625</u>
<u>48 through 71</u>	<u>1,122</u>

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The Energy savings from the refrigeration equipment tune up/maintenance is 5%⁸⁴⁰.

⁸⁴⁰ “Dairy Refrigeration Tune-up, Agriculture Potential Study Data.” Spreadsheet. Potential Study Survey Data tab shows the breakdown of Wisconsin dairy farms with existing milking equipment scenarios based on 2017 Wisconsin Focus on Energy Potential Study results. Compressor Modeling tab created by CESA10 using compressor model data from past projects

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$$kWh_{SAVED} = kWh_{SAVED}/day * Days$$
$$kWh_{SAVED}/day = [lbs\ milk/day * CP_{MILK} * (^{\circ}FIN - ^{\circ}FFINAL) / AEER_{COMPRESSOR} / 1,000] * SF$$

Where:

Days

= Number of days per year cows are milked. Assume 365 if unknown.

lbs milk/day

= Pounds of milk produced at farm facility per day (= 68 pounds of milk per cow)

CP_{Milk}

= Specific Heat of Milk
= 0.93 Btu/lb °F⁸⁴¹

ΔT_{milk}

= Change in Milk Temperature
= °F_{in} - °F_{final}
°F_{in} = Temperature of milk being supplied that needs to be cooled
= 98°F if no pre-cooler is used in operation;
= 68°F if a milk pre-cooler is used;

submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compress. Pre-cooler Measure Analysis tab showing sample data of 86 pre-cooler projects entered in Spectrum from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects.

841 Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration, Page 19.5.

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_____ = 56.3°F if a milk pre-cooler and VFD milk transfer pump are used.

T_{fs} _____ = Final stored temperature of cooled milk

_____ = 38°F

SF _____ = Savings factor for the percentage of energy able to be captured from the tune up process
= 5%

Summer Coincident Peak kW Savings Algorithm

The demand savings for this measure are deemed values depending on fan size and apply to all building types per the below table.

Diameter of Fan (inches)	kW
24 through 35	0.118
36 through 47	0.198
48 through 71	0.356

_____ n/a

Annual Fossil Fuel Savings Algorithm

_____ n/a

Annual Water Savings Algorithm

_____ n/a

Incremental Cost

The incremental capital cost for all fan sizes is \$150-per inch. _____ n/a

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Measure Life

The expected measure life is assumed to be 71 years as standard for tune up measures.

Operation and Maintenance Impacts

n/a

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High Volume, Low-Speed, Fans

Unique Measure Code(s): CI AG DAIRY TUNEUPS LV FANS

Effective Date: July 2024

End Date: TBD

Measure Description

High volume low speed (HVLS) fans provide air circulation to improve thermal comfort and indoor air quality. The measure applies to HVLS fans that are replacing multiple less efficient conventional fans in agricultural applications. This measure assumes single-speed, steady state operation for both baseline and efficient equipment. The efficient condition measure applies to 16-24 foot diameter horizontally mounted ceiling high volume low speed (HVLS) fans that are replacing multiple non-HVLS fans that have reached the end of useful life in agricultural applications, is refrigeration equipment associated with a commercial grade dairy farm facility that has been inspected and tuned up by a U.S. EPA 608 Certified Service Provider. The Service Provider must abide by all rules and regulations related to refrigerant testing and safety protocol and must conduct the following tasks: clean and inspect condenser and evaporator coils; clean drain pan; inspect/clean fans, screens, grills, filters, and drier cores; inspect/adjust heat reclaim operation; tighten all line voltage connections; inspect/replace relays and capacitors as needed; and add/remove refrigerant charge as needed.

Definition of Baseline Condition

As a retrofit measure, the actual existing conditions are taken as baseline. The number and wattage of the existing fans shall be used to define baseline energy consumption.

As a new construction measure, baseline is taken as the total operating wattage of conventional fans required to match the flow rate (CFM) rating of the efficient

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equipment. The baseline condition is refrigeration equipment associated with a commercial-grade dairy farm facility that has not been inspected or tuned up in more than 12 months.

Definition of Efficient Condition

The efficient equipment must be a fan with a diameter above 16 feet that meets program minimum efficiency requirements. This tune-up is designed to assess all refrigeration equipment associated with a commercial-grade dairy farm facility with the intention of reducing electrical consumption.

Annual Energy Savings Algorithm

$$\Delta kWh = \frac{\sum((N_{base} * Watts_{base}) - \sum(N_{re} * Watts_{re})) Btu_{Recovered} * DaysHours * (1/EF_{elec} 1000)}{(1/3,412)}$$

Where:

N_{base} = Number of baseline (conventional) fans being replaced (of equivalent wattage)
= Actual (for Retrofit projects). For new construction projects, the number of baseline fans should be set equivalent to the number of HVLS fans being installed.

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$Watts_{base}$ = Operating demand (W) of baseline fan
= Actual (Retrofit). For new construction projects refer to the New Construction HVLSconnected load savings table below.

N_{eff} = Number of efficient fans installed (of equivalent wattage)
= Actual

$Watts_{eff}$ = Operating demand (W) of efficient fan
= Actual (Retrofit). For new construction projects refer to the New Construction HVLSconnected load savings table below.⁸⁴²

Diameter of Fan (feet)	Watts_base	Watts_eff
16-17.9	4497	761
18-19.9	5026	850
20-23.9	5555	940
24 +	6613	1119

⁸⁴² KEMA 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F, Group 1 Programs, Volume 2 (Table 17). Typically, the number of baseline conventional circulation fans the HVLS fan is off-setting is not a one for one replacement scenario. Due to their more efficient design, a single HVLS fan can move and displace as much air as multiple conventional circulation fans. The baseline wattage represents the equivalent quantity of baseline fans and their wattages to match that of a single HVLS fan.

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Hours = Actual Hours of Operation. If unknown, use default values from the table below.⁸⁴³

Facility Type	Annual Hours of Operation
Hog	3597
Poultry	2,862
Dairy	2,578
Unknown/Other	3,259

= Actual

The Energy savings from the refrigeration equipment tune up/maintenance is 5%⁸⁴⁴.

⁸⁴³ Dairy Farm Energy Management Guide, Southern California Edison February, 2004. The guide recommends controlling fans in order to provide maximum ventilation as necessary at 72°F and above due to heat stress concerns on cows at and above that temperature. The 67°F balance point was developed assuming a 5°F temperature band, assuming the interior temperature of the barn will be greater than that outside due to internal heat gains.

⁸⁴⁴ "Dairy Refrigeration Tune-up, Agriculture Potential Study Data." Spreadsheet. Potential Study Survey Data tab shows the breakdown of Wisconsin dairy farms with existing milking equipment scenarios based on 2017 Wisconsin Focus on Energy Potential Study results. Compressor Modeling tab created by CESA10 using compressor model data from past projects submitted to Focus on Energy and Compressor Performance Data sheets from Copeland scroll compress. Pre-cooler Measure Analysis tab showing sample data of 86 pre-cooler projects entered in Spectrum from January 2015 to July 2016. The split of single pass to double pass plate coolers installed on Wisconsin dairies was determined from the project inputs of these 86 sample projects.

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$kWh_{SAVED} = kWh_{SAVED} / day * Days$

$kWh_{SAVED} / day = [lbs\ milk / day * CP_{,MILK} * (^{\circ}F_{IN} - ^{\circ}F_{FINAL}) / AEER\ COMPRESSOR / 1,000] * SF$

Where:

Days = Number of days per year cows are milked. Assume 365 if unknown.

lbs milk/day = Pounds of milk produced at farm facility per day (= 68 pounds of milk per cow)

$CP_{,Milk}$ = Specific Heat of Milk
= 0.93 Btu/lb ^{°F}⁸⁴⁵

ΔT_{milk} = Change in Milk Temperature
= $^{\circ}F_{in} - ^{\circ}F_{final}$

$^{\circ}F_{in}$ = Temperature of milk being supplied that needs to be cooled
= 98°F if no pre-cooler is used in operation;
= 68°F if a milk pre-cooler is used;
= 56.3°F if a milk pre-cooler and VFD milk transfer pump are used.

$^{\circ}F_{in}$ = Final stored temperature of cooled milk
= 38°F

845 Specific heat of whole milk, Table 3: Unfrozen Composition Data, Initial Freezing Point, and Specific Heat of Foods, 2014 ASHRAE Handbook - Refrigeration, Page 19.5.

SF = Savings factor for the percentage of energy able to be captured from the tune up process
=5%

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

As a retrofit measure, the actual installation cost should be used for screening and reporting purposes.

For a new construction measure, actual full installed costs may be used along with the following baseline cost assumptions:⁸⁴⁶ n/a

Diameter of Fan (feet)	Baseline Cost
16-17.9	\$1210
18-19.9	\$1460

⁸⁴⁶ Baseline full installed costs linearly extrapolated using cost data from the Illinois ActOnEnergy TRM No. 2010-4. Midpoints were used to establish a single cost for each fan diameter category. Costs rounded up to the nearest \$10.

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20-23.9	\$1840
24 +	\$2090

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If actual costs are unavailable for new construction, the incremental measure costs are as follows:⁸⁴⁷

Diameter of Fan (feet)	Incremental Cost
16-17.9	\$4100
18-19.9	\$4130
20-23.9	\$4190
24 +	\$4230

Measure Life

The expected measure life is assumed to be 10 years⁸⁴⁸ as standard for tune up measures:

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⁸⁴⁷ Incremental costs linearly extrapolated using cost data from the Illinois ActOnEnergy TRM No. 2010-4. Midpoints were used to establish a single cost for each fan diameter category. Costs rounded up to the nearest \$10.

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⁸⁴⁸ Average motor life is calculated by dividing the estimated motor life (35,000 hours) divided by the annual run hours, taken to be the unknown/other farm commodity type of 3,259 hours (see description of default run hours on following page); and rounded down to nearest whole year. Motor life source, U.S. Department of Energy Advanced Manufacturing Office, Motor Systems Tip Sheet #3.

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Operation and Maintenance Impacts
n/a

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Lighting End Use

LED Exit Sign

Unique Measure Code(s): CI_LT_EREP_LEDEXI_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the installation of an exit sign illuminated with light emitting diodes (LED). This measure should be limited to early replacement applications.

Note: While this measure is characterized as an early replacement, a dual baseline is not used as it is assumed that the existing fixture would have been maintained with new baseline lamps (and ballasts, if required) for the duration of the measure life.

Definition of Baseline Condition

The baseline condition is an existing exit sign with a non-LED light-source.

Definition of Efficient Condition

The efficient condition is a new exit sign illuminated with light emitting diodes (LED).

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

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- WattsBASE

= Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.⁸⁴⁹
- WattsEE

= Actual Connected load of LED exit sign
- HOURS

= Average hours of use per year
= 8,760⁸⁵⁰
- ISR

= In Service Rate or percentage of units rebated that get installed
= 1.00⁸⁵¹
- WHFe

= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (WattsBASE - WattsEE) / 1000 * ISR * WHFd * CF$$

Where:

- WHFd

= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.

⁸⁴⁹ Assumes a fluorescent illuminated exit sign. Wattage consistent with ENERGY STAR assumptions. See http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheets.pdf.

⁸⁵⁰ Assumes operation 24 hours per day, 365 days per year.

⁸⁵¹ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

= Varies by utility, building type, and equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

CF = Summer Peak Coincidence Factor for measure = 1.0⁸⁵²

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta \text{MMBTU} = (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta \text{kWh} / \text{WHFe}) * 0.00073.$$

Where:

0.7 = Aspect ratio⁸⁵³

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating⁸⁵⁴

0.75 = Assumed heating system efficiency⁸⁵⁵

⁸⁵² Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

⁸⁵³ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁸⁵⁴ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁸⁵⁵ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Annual Water Savings Algorithm
n/a

Incremental Cost
The lifecycle NPV incremental cost for this retrofit measure is \$35.⁸⁵⁶

Measure Life
The measure life is assumed to be 5 years.⁸⁵⁷

Operation and Maintenance Impacts

	Baseline
	CFL
Replacement Cost	\$8 ⁸⁵⁸
Component Life (years)	1.14 ⁸⁵⁹

⁸⁵⁶ Represents the full installed cost of an LED exit sign. LED exit signs can typically be purchased for ~\$25 (see http://www.exitlightco.com/Exit_Signs and “<http://www.simplyexit signs.com>”). Assuming replacing exit sign requires 15 minutes of a common building laborer’s time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately \$35.

⁸⁵⁷ To be ENERGY STAR labeled, an LED exit sign must be guaranteed to last at least 5 years, however, many manufacturers state that their lamps will maintain National Fire Protection Association compliant levels of luminance for 10 to 25 years.

⁸⁵⁸ Represents the full installed cost of a replacement fluorescent lamp. Replacement lamps can typically be purchased for \$3.38 (based on 2017 Apex analysis). Assuming lamp replacement requires 15 minutes of a common building laborer’s time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately \$8.

⁸⁵⁹ Assumes rated life of fluorescent replacement lamp is 10,000 hours. Assuming annual exit sign operating hours of 8,760, estimated lamp life is 1.14 years.

The calculated net present value of the baseline replacement costs are presented below⁸⁶⁰:

Baseline	NPV of Baseline Replacement Costs
	2017
CFL	\$26.92

⁸⁶⁰ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

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Solid State Lighting (LED) Recessed Downlight Luminaire

Unique Measure Code: CI_LT_TOS_SSLEDWN_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight luminaire in place of an incandescent downlight lamp (i.e. time of sale, including Midstream programs). The SSL downlight should meet the ENERGY STAR Luminaires Version 2.0-2 specification⁸⁶¹. The characterization of this measure should not be applied to other types of LEDs.

Note, this measure assumes the baseline is a Bulged Reflector (BR) lamp. This lamp type is generally the cheapest and holds by far the largest market share for this fixture type.

Definition of Baseline Condition

The baseline is the purchase and installation of a lamp meeting the EISA 2007 efficacy backstop with light output similar to a standard BR30-type incandescent downlight light bulb. See the "Baseline Adjustment" section below for additional discussion.

Definition of Efficient Condition

The efficient condition is the purchase and installation of an ENERGY STAR Solid State Lighting (LED) Recessed Downlight luminaire.

⁸⁶¹ ENERGY STAR specification can be viewed here:

https://www.energystar.gov/sites/default/files/Luminaires%20V2.2%20Final%20Specification_0.pdf

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Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) / 1,000) * ISR * HOURS * WHFe$$

Where:

WattsBase = Connected load of baseline lamp
= Find the equivalent baseline wattage based on the LED initial lumen output from the table below⁸⁶²; if unknown assume 23W.

Lower Lumen Range	Upper Lumen Range	2020+ WattsBase ⁸⁶³
400	449	*
450	499	*
500	649	*
650	1419	*
1420	1789	*
1790	2049	*
2050	2579	*
2580	3299	*
3300	4270	150

⁸⁶² Based on ENERGY STAR equivalence table;
http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumenshttps://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_brightnes

⁸⁶³ Different jurisdictions may have different implementation start dates for the 2020 baseline shift.

Lower Lumen Range	Upper Lumen Range	2020+ WattsBase ⁸⁶³
<i>*For lamps and fixtures < 3300 lumens, the baseline after 2020 should be calculated as WattsBase = (LumensEE / 45)⁸⁶⁴</i>		

- LumensEE

= Lumen output of efficient lamp.

= Actual. If unknown assume 650 lumens⁸⁶⁵.
- WattsEE

= Connected load of efficient lamp

= Actual. If unknown assume 9.2W ⁸⁶⁶
- ISR

= In Service Rate or percentage of units rebated that get installed.

= 1.0⁸⁶⁷
- HOURS

= Average hours of use per year

= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in

⁸⁶⁴ In 2020 the EISA backstop takes effect and the minimum efficacy for all lamps and fixtures becomes 45 lumens/W.
<https://www.energy.gov/sites/prod/files/2015/02/f19/UMPCchapter21-residential-lighting-evaluation-protocol.pdf>

⁸⁶⁵ Calculated using the minimum lumen output for a BR lamp of 650 lumens.
⁸⁶⁶ Calculated using the minimum lumen output for a BR lamp of 650 lumens and the 60 lumens per watt specified by ENERGY STAR v2. 1 for luminaires with a CRI < 90.

⁸⁶⁷ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

WHFe

Appendix D. Otherwise, use site specific annual operating hours information.⁸⁶⁸

= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.

= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF$$

Where:

WHFd

= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.

= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is

⁸⁶⁸ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

CF = Summer Peak Coincidence Factor for measure

= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75$$

$$= (-\Delta\text{kWh} / \text{WFHe}) * 0.00073$$

Where:

- 0.7 = Aspect ratio ⁸⁶⁹*
- 0.003413 = Constant to convert kWh to MMBTU*
- 0.23 = Fraction of lighting heat that contributes to space heating ⁸⁷⁰*
- 0.75 = Assumed heating system efficiency ⁸⁷¹*

Annual Water Savings Algorithm

n/a

⁸⁶⁹ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁸⁷⁰ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁸⁷¹ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment.

The lifecycle NPV incremental costs, based on an average value for a wide range of applicable LED lamps, are provided below for time of sale⁸⁷². If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.

Time of Sale
\$11

Measure Life

Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. However, measure life is not to exceed 15 years⁸⁷³. The fixture life should be assumed to be 25,000 hours for separable luminaires and 50,000 hours for inseparable luminaires⁸⁷⁴.

⁸⁷² Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLlMjfvz>.

⁸⁷³ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

⁸⁷⁴ The ENERGY STAR specification for solid state recessed downlights requires luminaires using LED lamps to maintain >=70% initial light output for 25,000 hours in an indoor application for separable luminaires and 50,000 for inseparable luminaires.

Operation and Maintenance Impacts

The leveled baseline replacement cost over the lifetime of the SSL is presented below.⁸⁷⁵ The key assumptions used in this calculation are documented below:

	BR-type Incandescent
Replacement Lamp Cost	\$7.77
Replacement Labor Cost	\$4.48
Component Life (years)	0.57 ⁸⁷⁶

The calculated net present value of the baseline replacement costs is \$210 for downlights featuring inseparable components and \$118 for downlights with replaceable parts⁸⁷⁷.

Baseline Adjustment

The Energy Independence and Security Act (EISA) of 2007 included an efficacy “backstop” requiring that all general service lamps sold meet or exceed an efficacy requirement of 45 lumens per watt by 1/1/2020. Further, the definition of general service lamps was broadened by two Final Rules published by the DOE on 1/19/2017 to

⁸⁷⁵ Costs are from Itron, Mid-Atlantic TRM Version 7.0 Incremental Costs Update, 2017. Component costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

⁸⁷⁶ Assumes rated life of BR incandescent bulb of 2,000 hours, based on product review. Lamp life is therefore $2,000/3,500 = 0.57$ years.

⁸⁷⁷ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

effectively cover all common lamp types.⁸⁷⁸ In December 2019, the DOE retracted the definition expansion and effectively eliminated the efficacy backstop.⁸⁷⁹ Regulatory uncertainty persists in that the new rule faces significant legal challenges⁸⁸⁰ and the current federal administration has signaled it's intent to revisit the issue. Given this volatility and the fact that market transformation in lighting is already well underway, this measure establishes baselines consistent with the broadened GSL definition and EISA efficacy backstop to better reflect true market conditions.

⁸⁷⁸ Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7276 (January 19, 2017) (to be codified at 10 CFR Part 430) and Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7322 (January 19, 2017) (to be codified at 10 CFR Part 430).

⁸⁷⁹ <https://www.regulations.gov/document/EERE-2018-BT-STD-0010-0450>

⁸⁸⁰ <https://thehill.com/policy/energy-environment/484559-energy-department-sued-over-lightbulb-efficiency-rollback>

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Delamping

Unique Measure Code(s): CI_LT_ERT_DELAMP_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the permanent removal of a lamp and the associated electrical sockets (or “tombstones”) from a fixture.

Definition of Baseline Condition

The baseline conditions will vary dependent upon the characteristics of the existing fixture.

Definition of Efficient Condition

The efficient condition will vary depending on the existing fixture and the number of lamps removed.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * WHFe$$

Where:

- WattsBASE* = Actual Connected load of baseline fixture
- WattsEE* = Actual Connected load of delamped fixture
- HOURS* = Average hours of use per year

WHFe = If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.⁸⁸¹
= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * WHFd * CF$$

Where:
WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is

⁸⁸¹ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

CF = Summer Peak Coincidence Factor for measure

= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073.$$

Where:

0.7 = Aspect ratio ⁸⁸²

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating ⁸⁸³

0.75 = Assumed heating system efficiency ⁸⁸⁴

⁸⁸² HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁸⁸³ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁸⁸⁴ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure is assumed to be \$18.50 per fixture.⁸⁸⁵

Measure Life

The measure life is assumed to be 15 years.⁸⁸⁶

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the measure life is \$2.79 per lamp⁸⁸⁷.

⁸⁸⁵ Assumes delamping a single fixture requires 15 minutes at an hourly rate of \$74 assuming population weighted average of electrician labor costs for the Mid-Atlantic region from Electrical Costs with RSMeans Data 2017.

⁸⁸⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

⁸⁸⁷ See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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Occupancy Sensor – Wall-, Fixture-, or Remote-Mounted

Unique Measure Code(s): CI_LT_RF_OSWALL_0518, CI_LT_RF_OSFIX/REM_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure defines the savings associated with installing a wall-, fixture, or remote-mounted occupancy sensor that switches lights off after a brief delay when it does not detect occupancy.

Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

Definition of Efficient Condition

The efficient condition is lighting that is controlled with an occupancy sensor.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_{connected} * HOURS * SVGe * ISR * WHFe$$

Where:

kWconnected = Assumed kW lighting load connected to control.
HOURS = Average hours of use per year.

	<i>= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.</i> ⁸⁸⁸
SVGe	<i>= Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.</i> <i>= 0.28</i> ⁸⁸⁹
ISR	<i>= In Service Rate or percentage of units rebated that get installed</i> <i>= 1.00</i> ⁸⁹⁰
WHFe	<i>= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.</i> <i>= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.</i>

Summer Coincident Peak kW Savings Algorithm

⁸⁸⁸ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

⁸⁸⁹ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

⁸⁹⁰ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

$$\Delta kW = kW_{\text{connected}} * SVGd * ISR * WHFd * CF$$

Where:

- SVGd* = Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.
= 0.14 ⁸⁹¹
- WHFd* = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume $WHFe = WHFd = 1.0$.
- CF* = Summer Peak Coincidence Factor for measure
= See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.

Illustrative examples – do not use as default assumption.

For example, a 400W connected load being controlled in a conditioned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 * 0.14 * 1.00 * 1.32 * 0.69$$

⁸⁹¹ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

= 0.051 kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75.$
 $= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073.$

Where:

- 0.7 = Aspect ratio⁸⁹²
- 0.003413 = Constant to convert kWh to MMBTU
- 0.23 = Fraction of lighting heat that contributes to space heating⁸⁹³
- 0.75 = Assumed heating system efficiency⁸⁹⁴

Annual Water Savings Algorithm

n/a

Incremental Cost

⁸⁹² HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.
⁸⁹³ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).
⁸⁹⁴ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

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The lifecycle NPV incremental cost for this time of sale measure is assumed to be \$130 for per control for an occupancy sensors without ultrasonic capabilities, \$176 per control for occupancy sensors with ultrasonic capabilities.⁸⁹⁵

Measure Life

The measure life is assumed to be 10 years.⁸⁹⁶

Operation and Maintenance Impacts

n/a

⁸⁹⁵ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLLMjfvz>.

⁸⁹⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

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Daylight Dimming Control

Unique Measure Code(s): CI_LT_TOS_DDIM_0518, CI_LT_RF_DDIM_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure defines the savings associated with installing a daylighting dimming control system to reduce electric lighting levels during periods of high natural light. Systems typical include daylight sensors, control electronics, and, if necessary, dimmable ballasts.

Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

Definition of Efficient Condition

The efficient condition is lighting that is controlled with a daylight dimming system capable of continuous dimming to reduce electric lighting to the lowest possible levels during periods of adequate natural light.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_{connected} \times HOURS \times SVG \times ISR \times WHFe$$

Where:

kW_{connected} = Assumed kW lighting load connected to control.
HOURS = Average hours of use per year

*= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.*⁸⁹⁷

- SVG

*= Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.
= 0.28*⁸⁹⁸
- ISR

*= In Service Rate or percentage of units rebated that get installed
= 1.00*⁸⁹⁹
- WHFe

*= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

⁸⁹⁷ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

⁸⁹⁸ Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. “Lighting Controls in Commercial Buildings.” The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180.

⁸⁹⁹ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

Summer Coincident Peak kW Savings Algorithm⁹⁰⁰

$$\Delta kW = kW_{connected} \times SVG \times ISR \times WHFd \times CF$$

Where:

- WHFd* = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.
- CF* = Summer Peak Coincidence Factor for measure
= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Illustrative examples – do not use as default assumption

For example, a 400W connected load being controlled in a conditioned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 \times 0.28 \times 1.00 \times 1.32 \times 0.69$$

⁹⁰⁰ As a conservative assumption, the peak demand savings algorithm assumes the same annual savings factor (SVG) as the energy savings equation. It is probable that higher than average availability of daylight coincides with summer peak periods. This factor is a candidate for future study as increased accuracy will likely lead to increased peak demand savings estimates.

= 0.10 kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75.$
 $= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073.$

Where:

- 0.7 = Aspect ratio⁹⁰¹
- 0.003413 = Constant to convert kWh to MMBTU
- 0.23 = Fraction of lighting heat that contributes to space heating⁹⁰²
- 0.75 = Assumed heating system efficiency⁹⁰³

Annual Water Savings Algorithm

n/a

Incremental Cost

⁹⁰¹ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.
⁹⁰² Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).
⁹⁰³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

The incremental cost for this time of sale measure is assumed to be \$100 per ballast controlled for both fixture-mounted and remote-mounted daylight sensors.⁹⁰⁴

Measure Life

The measure life is assumed to be 10 years.⁹⁰⁵

Operation and Maintenance Impacts

n/a

⁹⁰⁴ Northeast Energy Efficiency Partnerships Incremental Cost Study Report, Navigant, 2011. Assumes the simple average of cost of all photosensors types. Source does not differentiate costs between fixture and remote-mounted sensors.

⁹⁰⁵ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

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Advanced Lighting Design – Commercial

Unique Measure Code(s): CI_LT_NC_ADVLTNG_0615

Effective Date: June 2015

End Date: TBD

Measure Description

Advanced lighting design refers to the implementation of various lighting design principles aimed at creating a quality and appropriate lighting experience while reducing unnecessary light usage. This is often done by a professional in a new construction situation. Advanced lighting design uses techniques like maximizing task lighting and efficient fixtures to create a system of optimal energy efficiency and functionality to ultimately reduce the wattage required per square foot while maintaining acceptable lumen levels.

This measure characterization is intended for use in new construction or in existing buildings where significant lighting renovations are taking place and energy code requirements must be met.

Definition of Baseline Condition

The baseline condition assumes compliance with lighting power density requirements as mandated by Chapter 76 of the Delaware Code (2018 International

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Energy Conservation Code. For completeness, the lighting power density requirements for both the Building Area Method and the Space-by-Space Method are presented.⁹⁰⁶

Definition of Efficient Condition

The efficient condition assumes lighting systems that achieve lighting power densities below the maximum lighting power densities required by the relevant energy codes as described above. Actual lighting power densities should be determined on a site-specific basis.

Annual Energy Savings Algorithm⁹⁰⁷

$$\Delta kWh = ((LPDBASE - LPDEE) / 1000) * AREA * HOURS * WHFe$$

Where:

- LPDBASE

= Baseline lighting power density for building or space type (W/ft²). See tables below for values by jurisdiction and method.
- LPDEE

= Efficient lighting power density (W/ft²)
= Actual calculated
- AREA

= Building or space area (ft²)

⁹⁰⁶ Energy code lighting power density requirements can generally be satisfied by using one of two methods. The Building Area Method simply applies a blanket LPD requirement to the entire building based on the building type. Broadly speaking, as long as the total connected lighting wattage divided by the total floor space does not exceed the LPD requirement, the code is satisfied. The second method, the Space-by-Space Method, provides LPD requirements by space type based on the function of the particular space (e.g., “Hospital - Operating Room”, “Library - Reading Room”). LPD requirements must be satisfied for each individual space in the building. This method usually allows a higher total connected wattage as compared to the Building Area Method.

⁹⁰⁷ If the Space-by-Space Method is used, the total energy savings will be the sum of the energy savings for each individual space type.

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HOURS = Average hours of use per year
= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.⁹⁰⁸

WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Building Area Method Baseline LPD Requirements⁹⁰⁹

Building Area Type	Lighting Power Density
	Delaware
Automotive Facility	0.71
Convention Center	0.76
Court House	0.90

⁹⁰⁸ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

⁹⁰⁹ IECC 2018, Table C405.3.2 (1). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2016, Table 9.5.1.

	Lighting Power Density
Building Area Type	Delaware
Dining: Bar Lounge/Leisure	0.90
Dining: Cafeteria/Fast Food	0.79
Dining: Family	0.78
Dormitory	0.61
Exercise Center	0.65
Fire Station	0.53
Gymnasium	0.68
Healthcare-Clinic	0.82
Hospital	1.05
Hotel/Motel	0.75
Library	0.78
Manufacturing Facility	0.90
Motion Picture Theatre	0.83
Multifamily	0.68
Museum	1.06
Office	0.79
Parking Garage	0.15
Penitentiary	0.75

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	Lighting Power Density
Building Area Type	Delaware
Performing Arts Theatre	1.18
Police Station	0.80
Post Office	0.67
Religious Building	0.94
Retail	1.06
School/University	0.81
Sports Arena	0.87
Town Hall	0.80
Transportation	0.61
Warehouse	0.48
Workshop	0.90

Space-by-Space Method Baseline LPD Requirements⁹¹⁰

⁹¹⁰ IECC 2018, Table C405.3.2(2). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2016, Table 9.5.1.

Common Space-By-Space Types	Lighting Power Density (W/ft²)
Atrium	
Less than 40 feet in height	0.03 per foot in total height
Greater than 40 feet in height	0.40 + 0.02 per foot in total height
Audience seating area	
In an auditorium	0.63
In a convention center	0.82
In a gymnasium	0.65
In a motion picture theater	1.14
In a penitentiary	0.28
In a performing arts theater	2.03
In a religious building	1.53
In a sports arena	0.43
Otherwise	0.43
Banking activity area	0.86
Breakroom (See Lounge/Breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	1.34
Otherwise	0.96
Conference/meeting/multipurpose room	1.07

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Copy/print room	0.56
Corridor	
In a facility for the visually impaired (and not used primarily by staff)	0.92
In a hospital	0.92
In a manufacturing facility	0.29
Otherwise	0.66
Courtroom	1.39
Dining area	
In bar/lounge or leisure dining	0.93
In cafeteria or fast food dining	0.63
In a facility for the visually impaired (and not used primarily by staff)	2.00
In family dining	0.71
In a penitentiary	0.96
Otherwise	0.63
Electrical/mechanical room	0.43
Emergency vehicle garage	0.41
Food preparation area	1.06
Guest room	0.77
Laboratory	
In or as a classroom	1.20

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Otherwise	1.45
Laundry/washing area	0.43
Loading dock, interior	0.58
Lobby	
For an elevator	0.68
In a facility for the visually impaired (and not used primarily by the staff)	2.03
In a hotel	1.06
In a motion picture theater	0.45
In a performing arts theater	1.70
Otherwise	1.0
Locker room	0.48
Lounge/breakroom	
In a healthcare facility	0.78
Otherwise	0.62
Office	
Enclosed	0.93
Open plan	0.81
Parking area, interior	0.14
Pharmacy area	1.34
Restroom	

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In a facility for the visually impaired (and not used primarily by the staff)	0.96
Otherwise	0.85
Sales area	1.22
Seating area, general	0.42
Stairway (See space containing stairway)	
Stairwell	0.58
Storage room	0.46
Vehicular maintenance area	0.56
Workshop	1.14
Building Type Specific Space Types	Lighting Power Density (W/ft²)
Automotive (See Vehicular Maintenance Area above)	
Convention Center – exhibit space	0.88
Dormitory – living quarters	0.54
Facility for the visually impaired	
In a chapel (and not used primarily by the staff)	1.06
In a recreation room (and not used primarily by the staff)	1.80
Fire Station – sleeping quarters	0.20
Gymnasium/fitness center	
In an exercise area	0.50

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In a playing area	0.82
Healthcare facility	
In an exam/treatment room	1.68
In an imaging room	1.06
In a medical supply room	0.54
In a nursery	1.00
In a nurse's station	0.81
In an operating room	2.17
In a patient room	0.62
In a physical therapy room	0.84
In a recovery room	1.03
Library	
In a reading area	0.82
In the stacks	1.20
Manufacturing facility	
In a detailed manufacturing facility	0.93
In an equipment room	0.65
In an extra high bay area (greater than 50' floor-to-ceiling height)	1.05
In a high bay area (25'-50' floor-to-ceiling height)	0.75
In a low bay area (less than 25' floor-to-ceiling height)	0.96

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Museum	
In a general exhibition area	1.05
In a restoration room	0.85
Performing arts theater – dressing room	0.36
Post Office – Sorting Area	0.68
Religious buildings	
In a fellowship hall	0.55
In a worship/pulpit/choir area	1.53
Retail facilities	
In a dressing/fitting room	0.50
In a mall concourse	0.90
Sports arena – playing area	
For a Class I facility	2.47
For a Class II facility	1.96
For a Class III facility	1.70
For a Class IV facility	1.13
Transportation facility	
In a baggage/carousel area	0.45
In an airport concourse	0.31
At a terminal ticket counter	0.62
Warehouse – storage area	

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For medium to bulky, palletized items	0.35
For smaller, hand-carried items	0.69

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft² conditioned office building with gas heat using the Building Area Method with an LPDEE of 0.75:

$$\begin{aligned}\Delta kWh &= ((0.79 - 0.75) / 1000) * 15,000 * 2,969 * 1.10 \\ &= 2,400 kWh\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((LPDBASE - LPDEE) / 1000) * AREA * WHFd * CF$$

Where:

- WHFd

= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.

= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.
- CF

= Summer Peak Coincidence Factor for measure

= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft² conditioned office building with gas heat using the Building Area Method with an LPDEE of 0.75 and estimating PJM summer peak coincidence:

$$\begin{aligned}\Delta \text{kWh} &= ((0.79 - 0.75) / 1000) * 15,000 * 1.32 * 0.69 \\ &= 0.55 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\begin{aligned}\Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= (-\Delta \text{kWh} / \text{WHFe}) * 0.00073\end{aligned}$$

Where:

0.7 = Aspect ratio⁹¹¹

0.003413 = Constant to convert kWh to MMBTU

⁹¹¹ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

0.23 = Fraction of lighting heat that contributes to space heating ⁹¹²

0.75 = Assumed heating system efficiency ⁹¹³

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft² conditioned office building with gas heat using the Building Area Method with an LPDEE of 0.75:

$$\Delta kWh = (-7,348 / 1.10) * 0.00073$$
$$= -1.59 \text{ MMBTU}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs will vary greatly from project to project depending on the advanced lighting design principles and lighting technologies used. Incremental costs should be estimated on a case-by-case basis.

Measure Life

⁹¹² Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁹¹³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

The measure life is assumed to be 15 years.⁹¹⁴

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of the efficient and baseline replacement components, there may be significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs should be estimated on a case-by-case basis.

⁹¹⁴ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>. Assumes Advanced Lighting Design lifetime will be consistent with that of the “Fluorescent Fixture” measure from the reference document. This measure life assumes that the most common implementation of this measure will be for new construction or major renovation scenarios where new fixtures are installed. In such cases, adopting the fixture lifetime for the LPD reduction measure seems most appropriate.

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LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Luminaires and Retrofit Kits

Unique Measure Code(s): CI_LT_TOS_LEDODPO_0518, CI_LT_RF_LEDODPO_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of an LED outdoor pole/arm- or wall-mounted luminaire or retrofit kit for parking lot, street, or general area illumination in place of a high-intensity discharge light source. Eligible applications include time of sale or new construction and retrofit applications.

Definition of Baseline Condition

The baseline condition is defined as an outdoor pole/arm- or wall-mounted luminaire with a high intensity discharge light-source. Typical baseline technologies include metal halide (MH) and high pressure sodium (HPS) lamps.

Definition of Efficient Condition

The efficient condition is defined as an LED outdoor pole/arm- or wall-mounted luminaire or retrofit kit. Eligible fixtures and retrofit kits must be listed on the DesignLights Consortium Qualified Products List⁹¹⁵.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS}$$

⁹¹⁵ DesignLights Consortium Qualified Products List

<http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

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Where:

- WattsBASE = Actual Connected load of baseline fixture
= If the actual baseline fixture wattage is unknown, use the default values presented in the “Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage” table below.*
- WattsEE = Actual Connected load of the LED fixture
= If the actual LED fixture wattage is unknown, use the default values presented in the “Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage” table below based on the appropriate baseline description.*

Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage⁹¹⁶

⁹¹⁶ Baseline and efficient fixtures have been grouped into wattage categories based on typical applications. The typical baseline equipment in each group was weighted based on personal communication with Kyle Hemmi, CLEAResult on Sept. 18, 2012. Weighting reflects implementation program data from Texas, Nevada, Rocky Mountain, and Southwest Regions. When adequate program data is collected from the implementation of this measure in the Mid-Atlantic region, these weightings should be updated accordingly. Baseline fixture wattage assumptions developed from multiple TRMs including: Arkansas TRM Version 2.0, Volume 2: Deemed Savings, Frontier Associates, LLC, 2012; Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2012 Program Year - Plan Version, Massachusetts Electric and Gas Energy

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Measure Category	Baseline Description	WattsBASE	Efficient Description	WattsEE
LED Outdoor Area Fixture replacing up to 175W HID	175W or less base HID	171	DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires	99
LED Outdoor Area Fixture replacing 176-250W HID	176W up to 250W base HID	288	DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires	172
LED Outdoor Area Fixture replacing 251-400W HID	251W up to 400W base HID	452	DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires	293
LED Outdoor Area Fixture replacing 401-1000W HID	401W up to 1000W base HID	1075	DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires	663

HOURS = Average hours of use per year

Efficiency Program Administrators, 2011, and 2012 Statewide Customized Offering Procedures Manual for Business - Appendix B Table of Standard Fixture Wattages and Sample Lighting Table, Southern California Edison et al., 2012. As the total wattage assumptions for like fixtures typically do not vary by more than a few watts between sources, the values from the Arkansas document have been adopted here. Efficient fixture wattage estimated assuming mean delivered lumen equivalence between the baseline and efficient case. Baseline initial lamp lumen output was reduced by estimates of lamp lumen depreciation and optical efficiency. Efficient wattage and lumen information was collected from appropriate product categories listed in the DesignLights Consortium Qualified Products List - Updated 11/21/2012. Analysis presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" supporting workbook.

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*= If annual operating hours are unknown, assume 3,338 ⁹¹⁷.
Otherwise, use site specific annual operating hours information. ⁹¹⁸*

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\begin{aligned}\Delta \text{kWh} &= ((288 - 172) / 1000) * 3,338 \\ &= 387 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{CF}$$

Where:

$$\begin{aligned}\text{CF} &= \text{Summer Peak Coincidence Factor for measure} \\ &= 0 \text{ }^{919}\end{aligned}$$

Illustrative examples – do not use as default assumption

⁹¹⁷ Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

⁹¹⁸ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

⁹¹⁹ It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

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For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\Delta kW = ((288 - 172) / 1000) * 0$$
$$= 0 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV lifecycle incremental costs for time of sale and early replacement. If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.⁹²⁰

Measure Description	Time of Sale / New	Early Replacement

⁹²⁰ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLlMjfvz>.

LED Fixtures up to 150 W	\$228	\$419
LED Fixtures between 150W to 265W	\$750	\$1,002

Measure Life

Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000⁹²¹ hours. However, measure life is not to exceed 15 years⁹²².

Operation and Maintenance Impacts⁹²³

Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the

⁹²¹ The minimum rated lifetime for applicable products on the DesignLights Consortium Qualified Products List - Updated 4/14/2018 < <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/> > is 50,000 hours for exterior fixtures. Assuming average annual operating hours of 3,338 (Efficiency Vermont TRM User Manual No. 2014-85b; based on 5 years of metering on 235 outdoor circuits in New Jersey), the estimated measure life is 15 years.

⁹²² Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

⁹²³ Component information for the <175W HID and 176-250W HID categories adopted from Efficiency Vermont TRM User Manual No. 2012-77a. The remaining categories are based on a review of pricing for available products from <http://1000bulbs.com>. Accessed on 11/22/2012. NPV O&M Savings calculated assuming a 5% discount rate; detailed calculation presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" workbook.

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measure life is \$30.50 per lamp for time of sale and \$29.49 per lamp for early replacement⁹²⁴.

⁹²⁴ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

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LED High-Bay Luminaires and Retrofit Kits

Unique Measure Code(s): CI_LT_TOS_LEDHB_0518, CI_LT_RF_LEDHB_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of an LED high-bay luminaire or retrofit kit for general area illumination in place of a high-intensity discharge or fluorescent light source. Eligible applications include time of sale or new construction luminaires and retrofit kits installed at a minimum height of 20 feet. Because of the improved optical control afforded by LED luminaires and retrofit kits, LED lighting systems can typically reduce total lumen output while maintaining required illuminance on work surfaces. Therefore, illuminance calculations should be performed in the process of selecting LED luminaires.

Definition of Baseline Condition

The baseline condition is defined as a high-bay luminaire with a high intensity discharge or fluorescent light-source. Typical baseline technologies include pulse-start metal halide (PSMH) and fluorescent T5 high-output fixtures. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. light source technology, number of lamps). For retrofit applications, the baseline is the existing fixture.

Definition of Efficient Condition

The efficient condition is defined as an LED high-bay luminaire. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List⁹²⁵.

⁹²⁵ DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

- WattsBASE = Actual Connected load of baseline fixture
- WattsEE = Actual Connected load of the LED fixture
- HOURS = Average hours of use per year
= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.⁹²⁶
- ISR = In Service Rate or percentage of units rebated that get installed = 1.00⁹²⁷
- WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is

⁹²⁶ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

⁹²⁷ Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the “Equipment” category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

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unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * ISR * WHFd * CF$$

Where:

- WHFd

= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.

= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.
- CF

= Summer Peak Coincidence Factor for measure

= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 1.0 * 0.003413 * 0.23 / 0.75.$$

$$= (-\Delta kWh / WHFe) * 0.00073.$$

Where:

- 1.0 = Aspect ratio ⁹²⁸
- 0.003413 = Constant to convert kWh to MMBTU
- 0.23 = Fraction of lighting heat that contributes to space heating ⁹²⁹
- 0.75 = Assumed heating system efficiency ⁹³⁰

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV lifecycle incremental cost for time of sale and early replacement. If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.⁹³¹

⁹²⁸ As this measure will likely be installed in building types without defined perimeter zones (e.g., warehouses, gymnasiums, and manufacturing) no adjustment for perimeter zone aspect ratio is necessary.

⁹²⁹ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁹³⁰ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁹³¹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLlMjfvz>.

Measure Description	Time of Sale	Early Replacement
LED High Bay Fixture up to 220W	\$160	\$304
LED High Bay Fixture between 220 - 320W	\$397	\$555
LED High Bay Fixture greater than 320 W	\$1,013	\$1,188

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000⁹³² hours. However, measure life is not to exceed 15 years⁹³³.

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the

⁹³² Minimum DesignLights Consortium requirement is 50,000 hours for high bay fixtures. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

⁹³³ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

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measure life is \$32.50 per lamp for time of sale and \$31.63 per lamp for early replacement⁹³⁴.

⁹³⁴ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

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LED High-Intensity Discharge Screw Base

Unique Measure Code(s): CI_LT_TOS_LEDHID_0518, CI_LT_RF_LEDHID_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of a screw based LED lamp in place of a high-intensity discharge lamp. Eligible applications include time of sale or retrofit lamps.

Definition of Baseline Condition

The baseline condition is defined as a mogul (E39 or EX39) screw based high-intensity discharge bulb, using metal halide technology. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the lamp installed (e.g., wattage). For retrofit applications, the baseline is the existing bulb.

Definition of Efficient Condition

The efficient condition is defined as a mogul (E39 or EX39) screw-based LED lamp. Eligible bulbs must be listed on the DesignLights Consortium Qualified Products List.⁹³⁵

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR} * \text{WHFe}$$

Where:

⁹³⁵ DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>

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WattsBASE = Rated wattage of in-situ lamp. If the actual baseline lamp wattage is unknown, use the default values presented in the “LED Screw-Base Retrofit HID Lamps Baseline and Efficient Wattage” table below based on the appropriate baseline description.

LED Screw-Base Retrofit HID Lamps Baseline and Efficient Wattage⁹³⁶

Measure Category	Baseline Description	WattsBASE	Efficient Description	WattsEE
LED Retrofit Lamp replacing up to 175W HID	175W or less base HID	175	DLC Qualified LED Screw-In with Mogul Base (E39 or EX39)	45
LED Retrofit Lamp replacing 176-250W HID	176W up to 250W base HID	250	DLC Qualified LED Screw-In with Mogul Base (E39 or EX39)	75
LED Retrofit Lamp replacing 251-400W HID	251W up to 400W base HID	400	DLC Qualified LED Screw-In with Mogul Base (E39 or EX39)	132

WattsEE = Rated wattage of the LED replacement bulb
HOURS = Average hours of use per year
= If annual operating hours are unknown, for interior lamps see table “C&I Interior Lighting Operating Hours by Building Type” in

⁹³⁶ Baseline and efficient lamps have been grouped into wattage categories based on typical applications. Efficient wattage and lumen information was collected from appropriate product categories listed in the DesignLights Consortium Qualified Products List - Updated 3/16/2018.

Appendix D. For exterior lamps, assume 3,338⁹³⁷. Otherwise, use site specific annual operating hours information.⁹³⁸

ISR = In Service Rate or percentage of units rebated that get installed = 1.00⁹³⁹

WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is outdoors or unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}$$

⁹³⁷ Efficiency Vermont Technical Reference User Manual 2015-87C, March 2015; based on 5 years of metering on 235 outdoor circuits in New Jersey.

⁹³⁸ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

⁹³⁹ Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the “Equipment” category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

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Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or if the space is outdoors or unconditioned, assume *WHFe* = *WHFd* = 1.0.

CF = Summer Peak Coincidence Factor for measure
= For interior lamps, see table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.
= For exterior lamps, 0⁹⁴⁰

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 1.0 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta\text{kWh} / \text{WHFe}) * 0.00105$$

Where:

1.0 = Aspect ratio⁹⁴¹

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating⁹⁴²

⁹⁴⁰ It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

⁹⁴¹ As this measure will likely be installed in building types without defined perimeter zones (e.g., warehouses, gymnasiums, and manufacturing) no adjustment for perimeter zone aspect ratio is necessary.

⁹⁴² Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

0.75 = Assumed heating system efficiency⁹⁴³

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV lifecycle incremental cost for time of sale and early replacement.⁹⁴⁴

Measure Description	Time of Sale	Early Replacement
LED Retrofit Lamp replacing up to 175W HID	\$53	\$103
LED Retrofit Lamp replacing 176-250W HID	\$75	\$126
LED Retrofit Lamp replacing 251-400W HID	\$134	\$185

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number.

⁹⁴³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁹⁴⁴ Measure and baseline costs were calculated using bulb cost and specification data gathered from vendor websites in Q1 2018.

If rated life is unknown, then assume 50,000⁹⁴⁵ hours. However, measure life is not to exceed 15 years⁹⁴⁶.

Operation and Maintenance Impacts⁹⁴⁷

A baseline condition lamp with a typical 4-year lifetime would need to be replaced several times before an efficient condition lamp with a 12-year lifetime. The default net present value of savings over the measure life from avoided lamp replacements is \$23.27 per lamp for time of sale and \$23.80 for early replacement.

⁹⁴⁵ Minimum DesignLights Consortium requirement is 50,000 hours for applicable E39 replacement lamp products. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

⁹⁴⁶ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

⁹⁴⁷ Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the measure life. Cost information for baseline HID lamps is based on a review of pricing for available products from multiple online bulb vendors, conducted 3/16/2018. NPV O&M Savings calculated assuming a 5% discount rate; detailed calculation presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" workbook.

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LED 1x4, 2x2, and 2x4 Luminaires and Retrofit Kits

Unique Measure Code(s): CI_LT_TOS_LED1x4_0518, CI_LT_TOS_LED2x2_0615,
CI_LT_TOS_LED2x4_0518, CI_LT_RF_LED1x4_0518, CI_LT_RF_LED2x2_0518,
CI_LT_RF_LED2x4_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of an LED 1x4, 2x2, or 2x4 luminaire or retrofit kit for general area illumination in place of a fluorescent light source. These luminaires and retrofit kits are typically recessed, suspended, or surface-mounted and intended to provide ambient lighting in settings such as office spaces, schools, retail stores, and other commercial environments. Eligible applications include time of sale or new construction and retrofits applications. Because of the improved optical control afforded by LED luminaires and retrofit kits, LED lighting systems can typically reduce total lumen output while maintaining required illuminance on work surfaces. Therefore, illuminance calculations should be performed in the process of selecting LED luminaires and retrofit kits.

Definition of Baseline Condition

The baseline condition is defined as a 1x4, 2x2, or 2x4 fixture with a fluorescent light-source. Typical baseline technologies include fluorescent T8 fixtures. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. number of lamps).

Definition of Efficient Condition

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The efficient condition is defined as an LED high-bay luminaire. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List⁹⁴⁸.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

- WattsBASE

= Actual Connected load of baseline fixture
- WattsEE

= Actual Connected load of the LED fixture
- HOURS

= Average hours of use per year

= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.⁹⁴⁹

Otherwise, use site specific annual operating hours information.⁹⁵⁰
- ISR

= In Service Rate or percentage of units rebated that get installed

⁹⁴⁸ DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>

⁹⁴⁹ The lighting hours of use tables in Appendix D are primarily based on fluorescent lamp operating hours. It is assumed that, for general ambient lighting applications, LED operating hours will be similar to fluorescent operating hour; however, LED operating hours are a potential candidate for future study.

⁹⁵⁰ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

WHFe = 1.00⁹⁵¹
= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * ISR * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.

CF = Summer Peak Coincidence Factor for measure

⁹⁵¹ Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the “Equipment” category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta \text{MMBTU} = (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta \text{kWh} / \text{WHFe}) * 0.00073.$$

Where:

- 0.7 = Aspect ratio ⁹⁵²
- 0.003413 = Constant to convert kWh to MMBTU
- 0.23 = Fraction of lighting heat that contributes to space heating ⁹⁵³
- 0.75 = Assumed heating system efficiency ⁹⁵⁴

Annual Water Savings Algorithm

n/a

⁹⁵² HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁹⁵³ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁹⁵⁴ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV lifecycle incremental cost for time of sale and early replacement presented per kilolumen of luminaire initial lumen output. If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.⁹⁵⁵

Measure Description	Time of Sale (\$/klm)	Retrofit (\$/klm)
New LED linear recessed troffer/panel for 2x2, 1x4, and 2x4 luminaires	\$20	\$35
LED integrated retrofit kit for 2x2, 1x4 and 2x4 fixtures	\$22	\$37

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number.

⁹⁵⁵ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLlMjfvz>.

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If rated life is unknown, then assume 50,000⁹⁵⁶ hours. However, measure life is not to exceed 15 years⁹⁵⁷.

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the measure life is \$2.23 per kilolumen of luminaire initial lumen output for time of sale and \$3.00 per kilolumen of luminaire initial lumen output for early replacement⁹⁵⁸.

⁹⁵⁶ Minimum DesignLights Consortium requirement is 50,000 hours for both luminaires and retrofit kits. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

⁹⁵⁷ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

⁹⁵⁸ See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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LED Parking Garage/Canopy Luminaires and Retrofit Kits

Unique Measure Code(s): CI_LT_TOS_LEDODPG_0518, CI_LT_RF_LEDODPG_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the installation of an LED parking garage or fuel pump canopy luminaire or retrofit kit in place of a high-intensity discharge light source. Eligible applications include time of sale or new construction and retrofit applications.

Definition of Baseline Condition

The baseline condition is defined as a parking garage or canopy luminaire with a high intensity discharge light-source. Typical baseline technologies include metal halide (MH) and high pressure sodium (HPS) lamps.

Definition of Efficient Condition

The efficient condition is defined as an LED parking garage or canopy luminaire or retrofit kit. Eligible luminaires and retrofit kits must be listed on the DesignLights Consortium Qualified Products List⁹⁵⁹.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR$$

⁹⁵⁹ DesignLights Consortium Qualified Products List
<http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

Where:

WattsBASE = Actual Connected load of baseline fixture
= If the actual baseline fixture wattage is unknown, use the default values presented in the “Parking Garage or Canopy Fixture Baseline and Efficient Wattage” table below.

WattsEE = Actual Connected load of the LED fixture
= If the actual LED fixture wattage is unknown, use the default values presented in the “Parking Garage or Canopy Fixture Baseline and Efficient Wattage” table below based on the based on the appropriate baseline description.

Parking Garage or Canopy Fixture Baseline and Efficient Wattage⁹⁶⁰

⁹⁶⁰ Baseline and efficient fixtures have been grouped into wattage categories based on typical applications. The typical baseline equipment in each group were weightings based on personal communication with Kyle Hemmi, CLEAResult on Sept. 18, 2012. Weighting reflects implementation program data from Texas, Nevada, Rocky Mountain, and Southwest Regions. When adequate program data is collected from the implementation of this measure in the Mid-Atlantic region, these weightings should be updated accordingly. Baseline fixture wattage assumptions developed from multiple TRMs including: Arkansas TRM Version 2.0, Volume 2: Deemed Savings, Frontier Associates, LLC, 2012; Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2012 Program Year - Plan Version, Massachusetts Electric and Gas Energy

Measure Category	Baseline Description	WattsBASE	Efficient Description	WattsEE
LED Parking Garage/Canopy Fixture replacing up to 175W HID	175W or less base HID	171	DLC Qualified LED Parking Garage and Canopy Luminaires	94
LED Parking Garage/Canopy Fixture replacing 176-250W HID	176W up to 250W base HID	288	DLC Qualified LED Parking Garage and Canopy Luminaires	162
LED Parking Garage/Canopy Fixture replacing 251 and above HID	251W and above base HID	452	DLC Qualified LED Parking Garage and Canopy Luminaires	248

HOURS = Average hours of use per year

Efficiency Program Administrators, 2011, and 2012 Statewide Customized Offering Procedures Manual for Business - Appendix B Table of Standard Fixture Wattages and Sample Lighting Table, Southern California Edison et al., 2012. As the total wattage assumptions for like fixture typically do not vary by more than a few watts between sources, the values from the Arkansas document have been adopted here. Efficient fixture wattage estimated assuming mean delivered lumen equivalence between the baseline and efficient case. Baseline initial lamp lumen output was reduced by estimates of lamp lumen depreciation and optical efficiency. Efficient wattage and lumen information was collected from appropriate product categories listed in the DesignLights Consortium Qualified Products List - Updated 11/21/2012. Analysis presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" supporting workbook.

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= If annual operating hours are unknown, assume 3,338 for canopy applications and 8,760 for parking garage applications⁹⁶¹. Otherwise, use site specific annual operating hours information.⁹⁶²

ISR = In Service Rate or percentage of units rebated that get installed = 1.00⁹⁶³

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta \text{kWh} = ((288 - 162) / 1000) * 8,760 * 1.00$$

$$= 1104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{ISR} * \text{CF}$$

⁹⁶¹ Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey. Parking garages typically require artificial illumination 24 hours per day.

⁹⁶² Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

⁹⁶³ Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the “Equipment” category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

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Where:

CF

= Summer Peak Coincidence Factor for measure

= 0 for canopy applications and 1.0 for parking garage applications ⁹⁶⁴

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta kW = ((288 - 162) / 1000) * 1.00 * 1.00$$
$$= 0.13 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV lifecycle incremental cost for time of sale and early replacement. If additional detail is

⁹⁶⁴ It is assumed that efficient canopy lighting, when functioning properly, will never result in coincident peak demand savings. Parking garages typically require artificial illumination 24 hours per day and will therefore exhibit 100% peak coincidence.

needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.⁹⁶⁵

Measure Description	Time of Sale	Retrofit
LED Fixtures up to 150 W	\$631	\$809
LED Fixtures between 150W to 265W	\$1,314	\$1,521
LED Fixtures greater than 265 W	\$2,378	\$2,669

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000⁹⁶⁶ hours. However, measure life is not to exceed 15 years⁹⁶⁷.

⁹⁶⁵ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLlMjfvz>.

⁹⁶⁶ Minimum DesignLights Consortium requirement is 50,000 hours for both parking garage and canopy luminaires. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

⁹⁶⁷ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

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Operation and Maintenance Impacts⁹⁶⁸

Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the measure life is \$30.50 per lamp for time of sale and \$29.49 per lamp for early replacement for canopy applications and \$55.46 per lamp for time of sale and \$50.21 per lamp for early replacement for parking garage applications ⁹⁶⁹.

**ENERGY STAR Integrated Screw Based SSL (LED)
Lamp – Commercial**

Unique Measure Code: CI_LT_TOS_SSLEDWN_0518, CI_LT_EREP_SSLEDWN_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp V2.1 in place of an incandescent lamp. This includes lamps purchased through Midstream programs.

Definition of Baseline Condition

⁹⁶⁸ Component information for the <175W HID and 176-250W HID categories adopted from Efficiency Vermont TRM User Manual No. 2012-77a. The remaining category is based on a review of pricing for available products from <http://1000bulbs.com>. Accessed on 11/22/2012. NPV O&M Savings calculated assuming a 5% discount rate; detailed calculation presented in the “Mid Atlantic C&I LED Lighting Analysis.xlsx” workbook.

⁹⁶⁹ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

Time of Sale: The baseline wattage is assumed to be an incandescent or EISA complaint (where applicable) bulb installed in a screw-base socket.⁹⁷⁰ Note that the baseline will be EISA compliant for all categories to which EISA applies. If the in-situ lamp wattage is known and lower than the EISA mandated maximum wattage (where applicable), the baseline wattage should be assumed equal to the in-situ lamp wattage.

Early Replacement: The baseline wattage for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline wattage as defined above for the remainder of the measure life.

Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. The ENERGY STAR specifications can be viewed here:

<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification%201.pdf><http://1.usa.gov/1QJFLgT>.

Annual Energy Savings Algorithm

Time of Sale:

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

⁹⁷⁰ For text of Energy and Independence and Security Act, see <http://www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf>

Early Replacement⁹⁷¹:

ΔkWh for remaining life of existing unit:

$$\Delta kWh = ((WattsExist - WattsEE) / 1000) * HOURS * ISR * WHFe$$

ΔkWh for remaining measure life (i.e., measure life less the remaining useful life of existing equipment):

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBase = Based on lumens of the LED – find the equivalent baseline wattage from the table below.
NOTE: If WattsExist < WattsBase, then set WattsBase equal to the WattsExist.
NOTE: For early replacement measures use the appropriate year column in the table below relative to the end of the in-situ lamp useful life.

⁹⁷¹ The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
Omnidirectional, Medium Screw Base Lamps (A, BT, P, PS, S or T) (†, ‡see exceptions below)	250	309	*
	310	749	*
	750	1049	*
	1050	1489	*
	1490	2600	*
	2601	3300	*
	3301	3999	200
†S Shape <=749 lumens and T Shape <=749 lumens or T>10" length)	4000	6000	300
			*
	250	309	*
Decorative, Medium Screw Base (G Shape) (‡see exceptions below)	310	749	*
	250	309	*
	310	749	*
	750	1049	*
‡G16-1/2, G25, G30 <=499 lumens	1050	1300	*
	250	309	*
	310	349	*
‡G Shape with diameter >=5"	350	499	*
	250	349	*
	350	499	*
	500	574	*
	575	649	*
	650	1099	*

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
	1100	1300	*
Decorative, Medium Screw Base (B, BA, C, CA, DC, and F, and ST) (*see exceptions below)	70	89	*
	90	149	*
	150	299	*
	300	309	*
	310	499	*
	500	699	*
	70	89	*
*B, BA, CA, and F <=499 lumens	90	149	*
	150	299	*
	300	309	*
	310	499	*
			*
Omnidirectional, Intermediate Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	*
	310	749	*
†S Shape that have a first number symbol <= 12.5 and T Shape lamps with first number symbol <= 8 and nominal overall length <12"	250	309	*
	310	749	*
			*
Decorative, Intermediate Screw Base (G Shape) (‡see exceptions below)	250	309	*
	310	349	*
	350	499	*

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
‡G Shape with first numeral less than 12.5 or with diameter >=5"	250	349	*
	350	499	*
Decorative, Intermediate Screw Base (B, BA, C, CA, DC, and F, and ST)	70	89	*
	90	149	*
	150	299	*
	300	309	*
	310	499	*
Omnidirectional, Candelabra Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	*
	310	749	*
	750	1049	*
†S Shape that have a first number symbol <= 12.5 and T Shape with first number symbol <= 8 and nominal overall length <12"	250	309	*
	310	749	*
	750	1049	*
Decorative, Candelabra Screw Base (G Shape) (‡see exceptions below)	250	309	*
	310	349	*
	350	499	*
	500	574	*
‡G Shape with first numeral less than 12.5 or with diameter >=5"	250	349	*
	350	499	*
	500	574	*
	70	89	*

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
Decorative, Candelabra Screw Base (B, BA, C, CA, DC, and F, and ST)	90	149	*
	150	299	*
	300	309	*
	310	499	*
	500	699	*
Directional, Medium Screw Base, w/diameter <=2.25"	400	449	*
	450	499	*
	500	649	*
	650	1199	*
Directional, Medium Screw Base, R, PAR, ER, BR, BPAR or similar bulb shapes w/ diameter >2.5 " (**see exceptions below)	640	739	*
	740	849	*
	850	1179	*
	1180	1419	*
	1420	1789	*
	1790	2049	*
	2050	2579	*
	2580	3300	*
	3301	3429	120
	3430	4270	150
Directional, Medium Screw Base, R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26" and ≤ 2.5" (**see exceptions below)	540	629	*
	630	719	*
	720	999	*
	1000	1199	*
	1200	1519	*

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
	1520	1729	*
	1730	2189	*
	2190	2899	*
	2900	3300	*
	3301	3850	150
**ER30, BR30, BR40, or ER40	400	449	*
	450	499	*
	500	649-1179	*
**BR30, BR40, or ER40	650	1419	*
**R20	400	449	*
	450	719	*
**All reflector lamps below lumen ranges specified above			*
	200	299	
			*
ØRough service, shatter resistant, 3-way incandescent, and vibration service	300	399-639	
	250	309	*
	310	749	*
	750	1049	*
	1050	1489	*
	1490	2600	*
	2601	3300	*
	3301	3999	200
	4000	6000	300

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	Lower Lumen Range	Upper Lumen Range	2020+ WattsBase
<i>*For lamps and fixtures < 3300 lumens, the baseline after 2020 should be calculated as WattsBase = (LumensEE / 45)⁹⁷²</i>			
WattsEE	= Actual LED lamp watts.		
HOURS	= Average hours of use per year. = If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information. ⁹⁷³		
ISR	= In Service Rate or percentage of units rebated that are installed and operational = 1.00. ⁹⁷⁴		
WHFe	= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting. = Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is		

⁹⁷² See the “Baseline Adjustment” section below for additional details.

⁹⁷³ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

⁹⁷⁴ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

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unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

WattsExist = Rated wattage of existing in-situ lamp, if unknown set WattsExist equal to WattsBase.

LumensEE = Actual LED lumen output.

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}$$

Early Replacement⁹⁷⁵:

ΔkW for remaining life of existing unit:

$$\Delta kW = ((\text{WattsExist} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}$$

ΔkW for remaining measure life (i.e., measure life less the remaining useful life of existing equipment):

$$\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}$$

⁹⁷⁵ The two equations are provided to show how demand reduction is determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year demand reduction (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

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Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.

CF = Summer Peak Coincidence Factor for measure
= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm
Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073$$

Where:

0.7 = Aspect ratio.⁹⁷⁶

0.003413 = Constant to convert kWh to MMBTU.

0.23 = Fraction of lighting heat that contributes to space heating.⁹⁷⁷

⁹⁷⁶ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁹⁷⁷ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

0.75 = Assumed heating system efficiency.⁹⁷⁸

Annual Water Savings Algorithm
n/a

Incremental Cost

If the implementation strategy allows the collection of actual costs, or an appropriate average, then that should be used. If not, the lifecycle NPV incremental costs for time of sale replacements are provided below.⁹⁷⁹

Category	Time of Sale Incremental Cost
Unknown	\$2.52
Globe	\$3.36
Reflector	\$2.40
A Lamp	\$2.03
Candelabra	\$5.29

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number.

⁹⁷⁸ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁹⁷⁹ Cost assumptions are adapted from analysis provided by Apex Analytics LLC in April 2018.

If rated life is unknown, then assume 15,000⁹⁸⁰ hours. However, measure life is not to exceed 15 years⁹⁸¹.

Remaining Useful Life

RULhour

EULexist

RUL

= Remaining Useful Life calculated in hours.

*= EULexist – (HOURS * Age)*

= Remaining Useful Life calculated in years, rounded.

= RULhour / HOURS (with any fraction rounded)

NOTE:
If *RULhour* < 1000, set *RULhour* = 0.
If *RULhour* > *HOURS*, set *RULhour* = *HOURS*.

Where:

EULexist = Actual expected useful life of in-situ lamp. If useful life is unknown, then reference the table below.

	Expected Useful Life (Hours) ⁹⁸²
Omnidirectional, medium screw Base incandescent lamps, including decorative lamps.	1500
Directional incandescent lamps, including BR, PAR, G, MR, and other lensed and mirrored designs.	1500

⁹⁸⁰ Energy Star v2.1 requirement for all solid state (LED) lamps.
<<https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf>>

⁹⁸¹ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

⁹⁸² California DEER's Remote Ex-Ante Database Interface (READI) v.2.4.7

	Expected Useful Life (Hours) ⁹⁸²
Omnidirectional, medium screw base halogen lamps, including decorative lamps.	3500
Directional halogen lamps, including BR, PAR, G, MR, and other lensed and mirrored designs.	4000
All CFL spiral lamps, including omnidirectional, PAR, BR, decorative, and other shapes.	6000
All CFL double (DD), triple (Trpl), and quad style lamps.	10000
All CFL twin tube (TT) style lamps.	15000
All circular fluorescent lamps	12000

Age = Approximate age of existing lamp or time since lamp was last replaced in years. If unknown, assume 50% of EULbase remains.

Example of Remaining Useful Life calculation:

Twenty omnidirectional, medium-screw halogen lamps were installed approximately 15 months ago in a health care conference room and are now being retrofitted with LED lamps.

RULhour

$$\begin{aligned} &= EUL_{exist} - (HOU * Age) \\ &= 3500 - (1201 * 1.25) \\ &= 1,999 \end{aligned}$$

RULyear

$$\begin{aligned} &= RUL_{hour} / HOU \text{ (with any fraction rounded)} \\ &= 1999 / 1201 \text{ (with any fraction rounded)} \end{aligned}$$

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$$= 1.66 \text{ (with any fraction rounded)}$$
$$= 2$$

Operation and Maintenance Impacts

To account for the shift in baseline due to the Federal Legislation, the leveled baseline replacement cost over the lifetime of the LED is calculated. The key assumptions used in this calculation are documented below⁹⁸³:

	Price of Lamps that are EISA 2020 Compliant ⁹⁸⁴
Replacement Cost Unknown	\$3.12
Replacement Cost, Globe	\$6.56
Replacement Cost, Reflector	\$6.52
Replacement Cost, A Lamp	\$6.00
Replacement Cost, Candelabra	\$5.20
Component Life (hours)	6,000-10,000, depending on lamp style

The calculated default net present values of lamp replacements over the measure life for time of sale and replacement applications in the once EISA 2020 is presumed to be in effect are presented below⁹⁸⁵.

⁹⁸³ Baseline incandescent lamp cost assumptions are adapted from analysis provided by Apex Analytics LLC in April 2018.

⁹⁸⁴ Different jurisdictions may have different implementation start dates for the 2020 baseline shift.

⁹⁸⁵ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%. Analysis assumes that replacements in years 2018-2019 will experience one year of replacements with incandescent baseline components before shifting to a CFL baseline that is compliant with EISA 2020.

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Bulb Type	Time of Sale 2020+ ⁹⁸⁴⁸⁵⁴	Replacement 2020+ ⁹⁸⁴⁸⁵⁴
Unknown	\$3.14	\$4.27
Globe	\$12.35	\$13.05
Reflector	\$5.74	\$7.79
A Lamp	\$11.44	\$12.09
Candelabra	\$10.13	\$10.70

Baseline Adjustment

The Energy Independence and Security Act (EISA) of 2007 included an efficacy “backstop” requiring that all general service lamps sold meet or exceed an efficacy requirement of 45 lumens per watt by 1/1/2020. Further, the definition of general service lamps was broadened by two Final Rules published by the DOE on 1/19/2017 to effectively cover all common lamp types.⁹⁸⁶ In December 2019, the DOE retracted the definition expansion and effectively eliminated the efficacy backstop.⁹⁸⁷ Regulatory uncertainty persists in that the new rule faces significant legal challenges⁹⁸⁸ and the current federal administration has signaled it’s intent to revisit the issue. Given this volatility and the fact that market transformation in lighting is already well underway, this measure establishes baselines consistent with the broadened GSL definition and EISA efficacy backstop to better reflect true market conditions.

⁹⁸⁶ Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7276 (January 19, 2017) (to be codified at 10 CFR Part 430) and Energy Conservation Programs: Energy Conservation Standards for General Service Lamps, 82 Fed. Reg. 7322 (January 19, 2017) (to be codified at 10 CFR Part 430).

⁹⁸⁷ <https://www.regulations.gov/document/EERE-2018-BT-STD-0010-0450>

⁹⁸⁸ <https://thehill.com/policy/energy-environment/484559-energy-department-sued-over-lightbulb-efficiency-rollback>

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LED Four-pin based Lamp – Commercial

Unique Measure Code: CI_LT_TOS_LEDPL_0518, CI_LT_RF_LEDPL_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of a 4-pin (LED) Lamp in place of a 4-pin CFL lamp.

Definition of Baseline Condition

For time of sale replacement, the baseline is assumed to be a 4-pin CFL lamp. If the in-situ lamp wattage is known, the baseline wattage should be assumed equal to the in-situ lamp wattage.

Definition of Efficient Condition

The high efficiency condition is a DesignLights Consortium⁹⁸⁹ (DLC) qualified 4-pin LED lamp⁹⁹⁰.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

⁹⁸⁹ <https://www.designlights.org/>

⁹⁹⁰ DLC qualification is not required for LED lamps below 675 lumens.

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WattsBase = Actual wattage of in-situ lamp. If unknown find the equivalent baseline wattage based on the LED initial lumen output from the table below.

Lower Lumen Range	Upper Lumen Range	WattsBase ⁹⁹¹
760	934	13
935	1349	18
1350	1834	26
1835	2549	32
2550	3199	42

WattsEE = Actual LED lamp rated watts.
HOURS = Average hours of use per year.
= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.⁹⁹²
ISR = In Service Rate or percentage of units rebated that are installed and operational

⁹⁹¹ DOE and NREL TRM template for LED pin-base CFL replacements with input from stakeholders, “Tech to Utilities Draft Template_LED4Pin_20170919.xls”

⁹⁹² Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

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WHFe = 1.00.⁹⁹³
= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBase - WattsEE) / 1000) * ISR * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume *WHFe* = *WHFd* = 1.0.

CF = Summer Peak Coincidence Factor for measure
= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

⁹⁹³ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073$$

Where:

- 0.7

= Aspect ratio. ⁹⁹⁴
- 0.003413

= Constant to convert kWh to MMBTU.
- 0.23

= Fraction of lighting heat that contributes to space heating. ⁹⁹⁵
- 0.75

= Assumed heating system efficiency. ⁹⁹⁶

Annual Water Savings Algorithm

n/a

Incremental Cost

If the implementation strategy allows the collection of actual costs, or an appropriate average, then that should be used. If not, the lifecycle NPV incremental costs for time of sale replacements are provided below. These values are dependent on the baseline wattage of the CFL lamp.

⁹⁹⁴ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

⁹⁹⁵ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

⁹⁹⁶ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Lower Lumen Range	Upper Lumen Range	Time of Sale Incremental Cost ⁹⁹⁷
760	934	\$15
935	1349	\$13
1350	1834	\$24
1835	2549	\$23
2550	3199	\$11

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000⁹⁹⁸ hours. However, measure life is not to exceed 15 years⁹⁹⁹.

Operation and Maintenance Impacts¹⁰⁰⁰

⁹⁹⁷ Time of sale incremental cost includes cost of LED lamp and 0.25 hours of labor at \$19.91/hour minus the cost of the baseline CFL. Costs were determined by a Navigant review of pricing for available products from multiple online bulb vendors, conducted 3/26/2018.

⁹⁹⁸ Minimum DesignLights Consortium requirement. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

⁹⁹⁹ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

¹⁰⁰⁰ Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements over the measure life. Cost information for baseline CFL lamps is based on a Navigant review of pricing for available products from multiple online bulb vendors, conducted 3/26/2018. NPV O&M Savings calculated assuming a 5% discount rate and zero labor costs (self-installed replacements); detailed calculation presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" workbook.

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A baseline condition lamp with a typical 10,000-hour lifetime would need to be replaced several times before an efficient condition lamp with a 50,000-hour lifetime. The default net present value of savings over the measure life from avoided lamp replacements is \$7.17.

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LED Refrigerated Case Lighting

Unique Measure Code(s): CI_LT_TOS_LEDRL_0518, CI_LT_RF_LEDRL_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of LED luminaires in vertical and horizontal refrigerated display cases replacing T8 or T12HO linear fluorescent lamp technology. Savings characterizations are provided for both coolers and freezers. Specified LED luminaires should meet v2.1 DesignLights Consortium Product Qualification Criteria for either the “Vertical Refrigerated Case Luminaire” or “Horizontal Refrigerated Case Luminaires” category. LED luminaires not only provide the same light output with lower connected wattages, but also produce less waste heat which decreases the cooling load on the refrigeration system and energy needed by the refrigeration compressor. Savings and assumptions are based on a pre linear foot of installed lighting basis.

Definition of Baseline Condition

The baseline equipment is assumed to be T8 or T12HO linear fluorescent lamps.

Definition of Efficient Condition

The efficient equipment is assumed to be DesignLights Consortium qualified LED vertical or horizontal refrigerated case luminaires.

Annual Energy Savings Algorithm

$$\Delta kWh = (WattsPerLF_{BASE} - WattsPerLF_{EE}) / 1000 * LF * HOURS * WHFe.$$

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Where:

WattsPerLFBASE = Connected wattage per linear foot of the baseline fixtures; see table below for default values.¹⁰⁰¹

WattsPerLFEE = Connected wattage per linear foot of the LED fixtures.¹⁰⁰²

= Actual installed. If actual installed wattage is unknown, see table below for default values.

Efficient Lamp	Baseline Lamp	Efficient Fixture Wattage (WattsPerLFEE)	Baseline Fixture Watts (WattsPerLFBASE)
LED Case Lighting System	T8 Case Lighting System	7.6	15.2
LED Case Lighting System	T12HO Case Lighting System	7.7	18.7

LF = Linear feet of installed LED luminaires.

= Actual installed

HOURS = Annual operating hours; assume 6,205 operating hours per year if actual operating hours are unknown.¹⁰⁰³

¹⁰⁰¹ Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

¹⁰⁰² Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

¹⁰⁰³ Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes refrigerated case lighting typically operates 17 hours per day, 365 days per year.

WHFe = Waste heat factor for energy to account for refrigeration savings from efficient lighting. For prescriptive refrigerated lighting measures, the default value is 1.41 for refrigerated cases and 1.52 for freezer cases.¹⁰⁰⁴

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (WattsPerLFBASE - WattsPerLFEE) / 1000 * LF * WHFd * CF.$$

Where:

- WHFd

= Waste heat factor for demand to account for refrigeration savings from efficient lighting. For prescriptive refrigerated lighting measures, the default value is 1.40 for refrigerated cases and 1.51 for freezer cases.¹⁰⁰⁵
- CF

= Summer Peak Coincidence Factor for measure = 0.96 (lighting in Grocery).¹⁰⁰⁶

Annual Fossil Fuel Savings Algorithm

n/a

¹⁰⁰⁴ New York Department of Public Service. 2014. The New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs - Residential, Multi-family, and Commercial/Industrial Measures Version 2.

¹⁰⁰⁵ New York Department of Public Service. 2014. The New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs - Residential, Multi-family, and Commercial/Industrial Measures Version 2.

¹⁰⁰⁶ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

Annual Water Savings Algorithm

n/a

Incremental Cost¹⁰⁰⁷

Per Linear Foot
Time of Sale
\$23

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000¹⁰⁰⁸ hours. However, measure life is not to exceed 15 years¹⁰⁰⁹.

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of baseline lamps, actual operation and maintenance costs should be estimated on a case-by-case basis. If actual O&M costs are unknown, the calculated default net present value of lamp replacements (per linear foot) over the measure life is \$2.17 for time of sale applications¹⁰¹⁰.

¹⁰⁰⁷ Navigant. May 2014. Incremental Cost Study Phase Three Final Report. Prepared for NEEP Regional Evaluation, Measurement & Verification Forum

¹⁰⁰⁸ Minimum DesignLights Consortium requirement. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

¹⁰⁰⁹ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

¹⁰¹⁰ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

Exterior LED Flood and Spot Luminaires

Unique Measure Code(s): CI_LT_TOS_LEDFLS_0518 and CI_LT_RF_LEDFLS_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure relates to the installation of an exterior LED flood or spot luminaire for landscape or architectural illumination applications in place of a halogen incandescent or high-intensity discharge light source. Eligible applications include time of sale and new construction as well as retrofit applications.

Definition of Baseline Condition

The baseline condition is defined as an exterior flood or spot fixture with a high intensity discharge or PAR light-source. Typical baseline technologies include halogen incandescent parabolic aluminized reflector (PAR) lamps and metal halide (MH) luminaires.

Definition of Efficient Condition

The efficient condition is defined as an LED flood or spot luminaire. Eligible luminaires must be listed on the DesignLights Consortium Qualified Products List¹⁰¹¹.

Annual Energy Savings Algorithm

$$\Delta kWh = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS}.$$

Where:

¹⁰¹¹ DesignLights Consortium Qualified Products List <<https://www.designlights.org/qpl>>

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WattsBASE = Actual Connected load of baseline fixture
 = If the actual baseline fixture wattage is unknown, use the actual LED lumens to find equivalent baseline wattage from the table below.¹⁰¹²

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
PAR38	500	1000	52.5
	1000	4000	108.7
Metal Halide	4000	15000 ¹⁰¹³	205.0
Metal Halide	15000	20000	288
Metal Halide	20000	30000	460

WattsEE = Actual Connected load of the LED luminaire.
HOURS = Average hours of use per year.

¹⁰¹² Efficiency Vermont TRM User Manual No. 2014-85b; baseline are based on analysis of actual Efficiency Vermont installations of LED lighting. Exterior LED flood and spot luminaires are an evolving technology that may replace any number of baseline lamp and fixture types. It is recommended that programs track existing and new lamps and/or luminaire types, wattages, and lumen output in such way that baseline assumptions can be refined for future use.

¹⁰¹³ Source does not specify an upper lumen range for LED luminaires. Based on a review of manufacturer product catalogs, 15,000 lumens is the approximate initial lumen output of a 175W MH lamp.

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*= If annual operating hours are unknown, assume 3,338 ¹⁰¹⁴.
Otherwise, use site specific annual operating hours
information.¹⁰¹⁵*

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * CF.$$

Where:

*CF = Summer Peak Coincidence Factor for measure
= 0. ¹⁰¹⁶*

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV

¹⁰¹⁴ Efficiency Vermont TRM User Manual No. 2014-85b; based on 5 years of metering on 235 outdoor circuits in New Jersey.

¹⁰¹⁵ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

¹⁰¹⁶ It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

lifecycle incremental cost for time of sale and early replacement. If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.¹⁰¹⁷

Measure Description	Time of Sale / New	Early Replacement
LED PAR16	\$5	\$9
LED PAR20	\$10	\$15
LED PAR30	\$26	\$30
LED PAR38	\$33	\$38

Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000¹⁰¹⁸ hours. However, measure life is not to exceed 15 years¹⁰¹⁹.

¹⁰¹⁷ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

¹⁰¹⁸ Minimum DesignLights Consortium requirement. <<https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>>

¹⁰¹⁹ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

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Operation and Maintenance Impacts

Due to differences in costs and lifetimes of fixture components between the efficient and baseline cases, there are significant operation and maintenance impacts associated with this measure. O&M impacts should be determined on a case-by-case basis.¹⁰²⁰

¹⁰²⁰ Exterior LED flood and spot luminaires are an evolving technology that may replace any number of baseline lamp and fixture types. It is recommended that programs track existing and new lamps and/or luminaire types, wattages, lumen output, and costs in such way that generalized prescriptive O&M values can be developed for future use.

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Low Wattage Four-Foot Linear Fluorescent Replacement Lamps

Unique Measure Code(s): CI_LT_RF_FLTUBE_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the replacement of four-foot linear fluorescent lamps with low wattage four-foot linear fluorescent replacement lamps, as offered through the midstream programs.

Measure eligibility is limited to midstream programs.

Definition of Baseline Condition

The baseline condition is defined as an existing four-foot linear fluorescent fixture.

Definition of Efficient Condition

The efficient condition is defined as a four-foot linear fluorescent fixture retrofitted with low wattage four-foot linear fluorescent replacement lamp(s).

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe.$$

Where:

$WattsBASE = 28.2\ W$

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WattsEE = Wattage of actual lamp installed; see table below

Default Lamp Wattage Assumptions¹⁰²¹

Lamp/Ballast System	Per Lamp Wattage (W)
Assumed Baseline 32W T8 IS NLO	28.2
28W T8 Premium PRS NLO	24.6
25W T8 Premium PRS NLO	22

HOURS = Average hours of use per year.
= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.
Otherwise, use site specific annual operating hours information.¹⁰²²

ISR = In Service Rate or percentage of units rebated that get installed.

WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.

¹⁰²¹ Lamps assumed to be paired with a “normal ballast factor” ballast; ballast factor = 0.88. Note that this measure, presented on a per lamp basis, assumes no savings for reduced or eliminated ballast energy consumption.

¹⁰²² Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

= HVAC type is unknown for midstream measures. $WHFe = 1.0$.¹⁰²³

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * ISR * WHFd * CF.$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If lights are claimed to be interior, assume the space is cooled and see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If lights are placed in exterior spaces, assume $WHFe = WHFd = 1.0$.

CF = Summer Peak Coincidence Factor for measure.
= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\begin{aligned} \Delta MMBTU &= (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75 * HTM. \\ &= (-\Delta kWh / WHFe) * 0.00073. \end{aligned}$$

¹⁰²³ HVAC type is unknown for midstream measures. Territory includes both gas heat ($WHFe > 1$) and electric heat ($WHFe < 1$). Both heat types participate in the midstream program. An average $WHFe$ of 1.0 is assumed.

Where:

0.7	= Aspect ratio. ¹⁰²⁴
0.003413	= Constant to convert kWh to MMBTU.
0.23	= Fraction of lighting heat that contributes to space heating ¹⁰²⁵
0.75	= Assumed heating system efficiency. ¹⁰²⁶
HTM	= Heat Type Multiplier. If the space is identified as exterior, HTM = 0. If the space is identified as interior, or unknown, HTM = 22.4% = 0.224 ¹⁰²⁷

Annual Water Savings Algorithm
n/a

Incremental Cost
Incremental costs associated with linear fluorescent lamp replacement are \$2 per lamp¹⁰²⁸.

Measure Life

¹⁰²⁴ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.
¹⁰²⁵ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).
¹⁰²⁶ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.
¹⁰²⁷ Based on all aggregated prescriptive lighting savings tracking data in 2017 in Maryland, of heated interior spaces, with reported interior or exterior data, 22.4% of interior savings were heated by fossil fuels and 77.6% were heated using some type of electricity as the primary fuel.
¹⁰²⁸ This is the current midstream program buydown for Baltimore Gas and Electric: <https://bgesmartenergy.com/business/instant-lighting-discounts> (3/9/2018).

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Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 24,000 hours.¹⁰²⁹ However, measure life is not to exceed 15 years¹⁰³⁰.

Operation and Maintenance Impacts

Because this measure merely replaces linear fluorescent lamps with other linear fluorescent lamps, there are assumed to be no impacts to existing operation and maintenance.

¹⁰²⁹ The estimated lifetime for low wattage linear fluorescent lamps is 24,000 hours according to California DEERE's Remote Ex-Ante Database Interface (READI) v.2.4.7.

¹⁰³⁰ Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

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LED Four-Foot Linear Replacement Lamps

Unique Measure Code(s): CI_LT_RF_LED TUBE_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the replacement of four-foot linear fluorescent lamps with tubular, LED four-foot linear replacement lamps. Depending on the specific LED replacement lamp product, this measure may require changing the electrical wiring, replacing the ballast with an external driver, or altering the existing lamp holders (or “tombstones”) to accommodate the new lamp. Eligible applications are limited to retrofits. LED replacement lamp types are described in the table below:¹⁰³¹

LED Replacement Lamp Type	Description
Type A	The Type A lamp is designed with an internal driver that allows the lamp to operate directly from the existing linear fluorescent ballast. Most of these products are designed to work with T12, T8 and T5 ballasts.
Type B	The Type B lamp operates with an internal driver; however, the driver is powered directly from the main voltage supplied to the existing linear fluorescent fixture.
Type C	The Type C lamp operates with a remote driver that powers the LED linear lamp, rather than an integrated

¹⁰³¹ Underwriters Laboratories (UL) Standard 1598

	driver. The Type B lamp involves electrical modification to the existing fixture, but the low-voltage outputs of the driver are connected to the sockets instead of line voltage.

Measure eligibility is limited to “Type A” products that are powered by a new compatible T8 or T5 fluorescent electronic ballast installed at the same time as the LED replacement lamp or “Type C” products with an external LED driver.

Definition of Baseline Condition

The baseline condition is defined as an existing four-foot linear fluorescent fixture.

Definition of Efficient Condition

The efficient condition is defined as an as a four-foot linear fluorescent fixture retrofit with LED four-foot linear replacement lamp(s) and, if required, external driver. Eligible LED replacement lamp fixture wattage must be less than the baseline fixture wattage and listed on the DesignLights Consortium Qualified Products List¹⁰³².

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe.$$

Where:

WattsBASE = Actual connected load of baseline fixture.
= If actual baseline wattage is unknown, assume the “Delta Watts” from the table below based on existing lamp/ballast system.

¹⁰³² DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>

WattsEE = Actual connected load of the fixture with LED replacement lamps.
 = If actual baseline wattage is unknown, assume the “Delta Watts” from the table below based on existing lamp/ballast system.

Default Baseline and Efficient Lamp Wattage Assumptions¹⁰³³

Baseline Lamp/Ballast System	Baseline Lamp Wattage (WattsBASE)	Replacement Wattage (WattsEE)	Delta Watts
32W T8 IS NLO	29.5	23	6.5
28W T8 Premium PRS NLO	25	19	6
25W T8 Premium PRS NLO	22	16	6
28W T5 NLO ¹⁰³⁴	32	13	19

HOURS = Average hours of use per year.
 = If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.

¹⁰³³ California Technical Forum. February 2015. T8 LED Tube Lamp Replacement Abstract Revision # 0; Note that the “Delta Watts” values, presented on a per lamp basis, implicitly, and conservatively, assume no savings for reduced or eliminated ballast energy consumption.

¹⁰³⁴ The T5 wattage with ballast losses was sourced from:

<https://www.xcelenergy.com/staticfiles/xcel/Marketing/MN-Bus-Lighting-Input-Wattage-Guide.pdf>

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Otherwise, use site specific annual operating hours information.¹⁰³⁵

ISR = In Service Rate or percentage of units rebated that get installed.
= 1.00.¹⁰³⁶

WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * ISR * WHFd * CF.$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.

¹⁰³⁵ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

¹⁰³⁶ Because of LED linear replacement lamps have not been specifically evaluated in the Mid-Atlantic region an initial ISR of 1.0 is assumed. However, costs of these products continue to drop rapidly increasing the probability that participants may purchase additional stock to be installed at a later date. This factor should be considered for future evaluation work.

= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

CF = *Summer Peak Coincidence Factor for measure.*
= *See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.*

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073.$$

Where:

0.7 = *Aspect ratio.* ¹⁰³⁷

0.003413 = *Constant to convert kWh to MMBTU.*

0.23 = *Fraction of lighting heat that contributes to space. heating* ¹⁰³⁸

¹⁰³⁷ HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

¹⁰³⁸ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

0.75 = Assumed heating system efficiency.¹⁰³⁹

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs (equipment and labor) LED linear replacement lamps are as follows:¹⁰⁴⁰

- Type A: \$22.67 per LED replacement lamp.
- Type C: \$22.67 per LED replacement lamp, \$15.07 for the external driver.

Measure Life

Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000¹⁰⁴¹ hours. However, measure life is not to exceed 15 years¹⁰⁴².

¹⁰³⁹ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

¹⁰⁴⁰ Based on a review of incremental cost estimates from California Technical Forum. February 2015. T8 LED Tube Lamp Replacement Abstract Revision # 0, Efficiency Vermont TRM User Manual No. 2014-85b, and online wholesalers. As this measure is a retrofit-type, incremental costs assume the full cost of replacement of the lamps and (removal of) the ballast(s).

¹⁰⁴¹ The minimum rated lifetime for applicable products on the DesignLights Consortium Qualified Products List - Updated 4/14/2018 < <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/> > is 50,000 hours for linear LED lamps.

¹⁰⁴² Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of fixture components between the efficient and baseline cases, there are significant operation and maintenance impacts associated with this measure. O&M impacts should be determined on a case-by-case basis.¹⁰⁴³

¹⁰⁴³ Fluorescent LED replacement lamps luminaires are an evolving technology that may replace any number of baseline lamp types. It is recommended that programs track existing and new lamps types, wattages, lumen output, and costs in such way that generalized prescriptive O&M values can be developed for future use.

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Networked Lighting Controls

Unique Measure Code(s): CI_LT_RF_NLC_0619, CI_LT_NC_NLC_0619

Effective Date: June 2019

End Date: TBD

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Measure Description

This measure defines the savings associated with installing a networked controlled lighting system. The control system must include luminaire-level lighting control (LLLC) that can switch lights on and off based on occupancy and is capable of full-range dimming based on local light levels. Note: Because networked lighting controls are required to include occupancy sensors and daylight harvesting, savings from occupancy sensors and daylight dimming control cannot be claimed separately. Additional savings may be achieved at no additional cost on a site-specific basis by implementing high-end trimming, personalized local controls, and customized scheduling with no need for additional equipment or software.

The analysis described in this measure is based on a study of multiple buildings and the associated savings is averaged by building type. On aggregate the calculated savings presented should agree with the average savings achieved on a program with multiple networked lighting controls projects but may not align with the savings achieved on an individual project. It is therefore recommended for large projects the analysis be handled with a custom calculation rather than the deemed savings presented here.

Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

Definition of Efficient Condition

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Annual Energy Savings Algorithm

Where:

SVG

¹⁰⁴⁴ Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

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	(Energy) ¹⁰⁴⁶
Assembly	0.23
Manufacturing	0.30
Office	0.63
School	0.28
Restaurant	0.47
Retail	0.44
Warehouse	0.82
Other	0.47

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BLC = Baseline Lighting Control factor. See table below.

Installation Type	Baseline Lighting Control Factor
Retrofit – Space with pre-existing occupancy or photo sensors	0.28
Retrofit – Space with no pre-existing controls	0.00
New Construction – Space with occupancy sensors required by code ¹⁰⁴⁷	0.28
New Construction – Occupancy sensors not required by code	0.00

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¹⁰⁴⁶ Findings from Networked Lighting Control energy savings come from DLC report: Energy Savings from Networked Lighting Control (NLC) Systems, 2017 modified to reflect Mid-Atlantic metering study lighting baseline hours of use. This change supported by NLC - LRC Literature Review, dated November 19, 2015.

¹⁰⁴⁷ See local appropriate code documentation for occupancy sensor requirements.

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ISR

= In Service Rate or percentage of units rebated that get installed

= 1.00

WHF_e

= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.

= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHF_e = WHF_d = 1.0.

Summer Coincident Peak kW Savings Algorithm
Lacking sufficient research to support unique peak demand savings calculations, the peak demand savings will conservatively be assumed to match those attributed to standard non-networked controls.

$$\Delta kW = kW_{connected} * (SVG - BLC) * ISR * WHF_d * CF$$

Where:

WHF_d

= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.

= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHF_e = WHF_d = 1.0.

CF

= Summer Peak Coincidence Factor for measure

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= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta\text{MMBTU} = (-\Delta\text{kWh} / \text{WHF}_e) * 0.003413 * 0.23 / 0.75$$
$$= -\Delta\text{kWh} * 0.00105$$

Where:

- 0.003413

= Constant to convert kWh to MMBTU
- 0.23

= Fraction of lighting heat that contributes to space heating¹⁰⁴⁸
- 0.80

= Assumed heating system thermal efficiency¹⁰⁴⁹

Annual Water Savings Algorithm

n/a

Incremental Cost

¹⁰⁴⁸ Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

¹⁰⁴⁹ Typical heating system thermal efficiency of 80%, consistent with minimum current federal standards for fossil fuel-fired systems.

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The incremental cost for the network-controlled systems is assumed to be \$2.06 per square foot.¹⁰⁵⁰ However costs can vary project to project. For larger projects where savings is being calculated with a custom analysis, the incremental cost should be calculated from actual installation costs (including labor and commissioning) minus any baseline costs such as energy code required lighting controls in new construction.

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Measure Life

The measure life is assumed to be 10 years.¹⁰⁵¹

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Operation and Maintenance Impacts

n/a

¹⁰⁵⁰ This represents an average of per-square-foot estimates from a NEEP study, a NEEA study, and a Lawrence Berkeley National Labs study.

NEEP, Advanced LED Controls: Emerging Technology Incremental Costs.

<https://www.neep.org/sites/default/files/AdvLEDcontrols.xlsx>

NEEA, Enlighted Technical Proof of Concept Study.

<https://conduitnw.org/Pages/File.aspx?RID=1656>

LBNL, Wireless Advanced Lighting Controls Retrofit Demonstration, https://nextenergy.org/wp-content/uploads/2018/03/GSA_Wireless-Adv-Lighting-Control-Retrofit-Demo_Apr-2015.pdf

¹⁰⁵¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007,

<http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>

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Heating Ventilation and Air Conditioning (HVAC) End Use

Unitary HVAC Systems

Unique Measure Code(s): CI_HV_TOS_HVACSYS_0518, CI_HV_EREP_HVACSYS_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure documents savings associated with the installation of new [commercial](#) heating, ventilating, and air conditioning systems exceeding baseline efficiency criteria in place of an existing system or a new standard efficiency system of the same capacity. This measure covers air conditioners (including unitary air conditioners and packaged terminal AC) and heat pumps (air source and packaged terminal heat pumps). It does not cover ductless mini-split units. This measure applies to time of sale, new construction, and early replacement opportunities.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a new system meeting minimum efficiency standards as presented in the 2018 International Energy Conservation Code (IECC 2018) (see table “Baseline Efficiencies by System Type and Unit Capacity” below) or federal standards where more stringent than local energy codes.

Early Replacement: The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.

Definition of Efficient Condition

The efficient condition is an HVAC system of the same type as the baseline system exceeding baseline efficiency levels.

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Baseline Efficiencies by System Type and Unit Capacity

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (IECC 2018 or Federal Standard)
Air Conditioners, Air Cooled		
<65,000 BTU/h	Split system	13.0 SEER
	Single package	14.0 SEER
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	11.3 EER 12.9 IEER
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	11.0 EER 12.4 IEER
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	10.0 EER 11.6 IEER
≥760,000 BTU/h	Split system and single package	9.7 EER 11.2 IEER
Air Conditioners, Water Cooled		
<65,000 BTU/h	Split system and single package	12.1 EER 12.3 IEER
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	12.1 EER 13.9 IEER
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	12.5 EER 13.9 IEER
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	12.4 EER 13.6 IEER

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Size Category (Cooling Capacity)	Subcategory	Baseline Condition (IECC 2018 or Federal Standard)
≥760,000 BTU/h	Split system and single package	12.2 EER 13.5 IEER
Air Conditioners, Evaporatively Cooled		
<65,000 BTU/h	Split system and single package	12.1 EER 12.3 IEER
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	12.1 EER 12.3 IEER
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	12.0 EER 12.2 IEER
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	11.9 EER 12.1 IEER
≥760,000 BTU/h	Split system and single package	11.7 EER 11.9 IEER
Heat Pumps, Air Cooled ¹⁰⁵²		
<65,000 BTU/h	Split System	14.0 SEER 8.2 HSPF
	Single Package	14.0 SEER 8.0 HSPF
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	11.2 EER 12.2 IEER 3.3 COP
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	10.6 EER 11.6 IEER 3.2 COP

¹⁰⁵² Heating mode efficiencies for heat pumps ≥65,000 BTU/h are provided at the 47°F db/43° wb outdoor air rating condition.

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Size Category (Cooling Capacity)	Subcategory	Baseline Condition (IECC 2018 or Federal Standard)
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	9.5 EER 10.6 IEER 3.2 COP

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards) ¹⁰⁵³
Packaged Terminal Air Conditioners ^{1054,1055}		
All Capacities	New Construction (Standard Size)	14.0 – (0.300 * Cap/1000) EER
All Capacities	Replacement (Non-Standard Size)	10.9 – (0.213 * Cap/1000) EER

¹⁰⁵³ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.96 (2016).

¹⁰⁵⁴ Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

¹⁰⁵⁵ “Cap” = The rated cooling capacity of the project in BTU/h. If the unit’s capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit’s capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations.

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards) ¹⁰⁵³
Packaged Terminal Heat Pumps ^{1056,1057}		
All Capacities	New Construction (Standard Size)	14.0 – (0.300 * Cap/1000) EER 3.7 – (0.052 * Cap/1000) COP
All Capacities	Replacement (Non-Standard Size)	10.8 – (0.213 * Cap/1000) EER 2.9 – (0.026 * Cap/1000) COP

Notes: 1) All cooling mode efficiency ratings in the table above assume electric resistance heating section type (or none). Subtract 0.2 from each baseline efficiency rating value if unit has heating section other than electric resistance.

Annual Energy Savings Algorithm

Air Conditioners (includes air-, water-, and evaporatively-cooled unitary ACs and PTACs)

Time of Sale:

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

¹⁰⁵⁶ Replacement unit shall be factory labeled as follows: “MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS.” Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

¹⁰⁵⁷ “Cap” = The rated cooling capacity of the project in BTU/h. If the unit’s capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit’s capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations.

$$\Delta kWh = (BTU/h_{COOL}/1000) * ((1/SEERBASE) - (1/SEEREE)) * HOURS_{COOL}$$

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (EER) as follows:

$$\Delta kWh = (BTU/h_{COOL}/1000) * ((1/IEERBASE) - (1/IEEREE)) * HOURS_{COOL}$$

For all PTACs, the energy savings are calculated using the Energy Efficiency Ratio (EER) as follows:

$$\Delta kWh = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * HOURS_{COOL}$$

Early Replacement¹⁰⁵⁸:

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$$\begin{aligned} \Delta kWh \text{ for remaining life of existing unit:} \\ = (BTU/h_{COOL}/1000) * ((1/SEEREXIST) - (1/SEEREE)) * HOURS_{COOL} \end{aligned}$$

¹⁰⁵⁸ The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

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ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (BTU/h_{COOL}/1000) * ((1/SEERBASE) - (1/SEEREE)) * HOURS_{COOL}$$

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (IEER) as follows:

ΔkWh for remaining life of existing unit:

$$= (BTU/h_{COOL}/1000) * ((1/IEEREXIST) - (1/IEEREE)) * HOURS_{COOL}$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (BTU/h_{COOL}/1000) * ((1/IEERBASE) - (1/IEEREE)) * HOURS_{COOL}$$

For all PTACs, the energy savings are calculated using the Energy Efficiency Ratio (EER) as follows:

ΔkWh for remaining life of existing unit:

$$= (BTU/h_{COOL}/1000) * ((1/EEREXIST) - (1/EEREE)) * HOURS_{COOL}$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * HOURS_{COOL}$$

Heat Pumps (includes air-source HPs and PTHPs)

Time of Sale:

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For units with capacities less than 65,000 BTU/h (except PTHPs), the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) and Heating Season Performance (HSPF) as follows:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEERBASE) - (1/SEEREE)) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPFBASE) - (1/HSPFEE)) * HOURS_{HEAT}.$$

For units with capacities greater than or equal to 65,000 BTU/h (except PTHPs), the energy savings are calculated using the Integrated Energy Efficiency Ratio (IEER) and Coefficient of Performance (COP) as follows:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEERBASE) - (1/IEEREE)) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) - (1/COPEE)) * HOURS_{HEAT}.$$

For all PTHPs, the energy savings are calculated using the Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) - (1/COPEE)) * HOURS_{HEAT}.$$

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Early Replacement¹⁰⁵⁹:

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) and Heating Season Performance (HSPF) as follows:

ΔkWh for remaining life of existing unit:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEER_{EXIST}) - (1/SEER_{EE})) * HOURS_{COOL}$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPF_{EXIST}) - (1/HSPF_{EE})) * HOURS_{HEAT}$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEER_{BASE}) - (1/SEER_{EE})) * HOURS_{COOL}$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPF_{BASE}) - (1/HSPF_{EE})) * HOURS_{HEAT}$$

¹⁰⁵⁹ The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

ΔkWh for remaining life of existing unit:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEER_{EXIST}) - (1/IEER_{EE})) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEX_{EXIST}) - (1/COPEE)) * HOURS_{HEAT}.$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEER_{BASE}) - (1/IEER_{EE})) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COP_{BASE}) - (1/COPEE)) * HOURS_{HEAT}.$$

For all PTHPs, the energy savings are calculated using the Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

ΔkWh for remaining life of existing unit:

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$

$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EER_{EXIST}) - (1/EER_{EE})) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEX_{EXIST}) - (1/COPEE)) * HOURS_{HEAT}.$$

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ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}.$$
$$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * HOURS_{COOL}.$$
$$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) - (1/COPEE)) * HOURS_{HEAT}.$$

Where:

- ΔkWh_{COOL}
 ΔkWh_{HEAT}
 BTU/h_{COOL}
 BTU/h_{HEAT}
 $SEEREE$
 $SEERBASE$
 $SEEREXIST$
 $HSPFEE$
 $HSPFBASE$
 $HSPFEXIST$
- = Annual cooling season electricity savings (kWh).
= Annual heating season electricity savings (kWh).
= Cooling capacity of equipment in BTU/hour.
= Actual Installed.
= Heating capacity of equipment in BTU/hour.
= Actual Installed.
= SEER of efficient unit.
= Actual Installed.
= SEER of baseline unit.
= Based on IECC 2018 for the installed capacity. See table above.
= SEER of the existing unit.
= Actual.
= HSPF of efficient unit.
= Actual Installed.
= HSPF of baseline unit.
= Based on IECC 2018 for the installed capacity. See table above.
= HSPF of the existing unit.

	= Actual.
IEEREE	= IEER of efficient unit.
	= Actual Installed.
IEERBASE	= IEER of baseline unit.
	= Based on IECC 2018 for the installed capacity. See table above.
IEEREXIST	= IEER of the existing unit.
	= Actual.
COPEE	= COP of efficient unit.
	= Actual Installed.
COPBASE	= COP of baseline unit.
	= Based on IECC 2018 for the installed capacity. See table above.
COPEXIST	= COP of the existing unit.
	= Actual.
EERBASE	= EER of baseline unit.
	= Based on IECC 2018 for the installed capacity. See table above.
EEREE	= EER of efficient unit (If the actual EER is unknown, it may be approximated by using the following equation: $EER = SEER/1.2$)
	= Actual installed.
EEREXIST	= EER of existing unit.
	= Actual.
3412	= Conversion factor (BTU/kWh).
HOURS _{COOL}	= Full load cooling hours. ¹⁰⁶⁰

¹⁰⁶⁰ From U.S. DOE. 2013. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*: “Although the EFLH is calculated with reference to a peak kW derived from EER, it is acceptable to use these EFLH with SEER or IEER. Some inconsistency occurs in using full-load hours with efficiency ratings measured at part loading, but errors in calculation are thought to be small relative to the expense and complexity of developing hours-of-use estimates precisely consistent with SEER and IEER.”

$HOURS_{HEAT}$ = If actual full load cooling hours are unknown, see table “Full Load Cooling Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load cooling hours information.
= Full load heating hours.
= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$\Delta kW = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * CF.$

Early Replacement:

ΔkW for remaining life of existing unit:
 $= (BTU/h_{COOL}/1000) * ((1/EEREXIST) - (1/EEREE)) * CF.$

ΔkW for remaining measure life (i.e., measure life less the remaining life of existing unit):
 $= (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * CF.$

Where:

CF_{PJM} = PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather

CF_{UPeak}

= 0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.¹⁰⁶¹

= Utility Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).

= 0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.¹⁰⁶²

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental costs for time of sale and early replacement units are provided in the tables below.¹⁰⁶³ Prescribed values vary depending on the current

¹⁰⁶¹ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011.

¹⁰⁶² C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011.

¹⁰⁶³ Default incremental costs assumptions for water- and evaporatively-cooled ACs, PTACs, and PTHPs will be addressed in subsequent versions of the TRM, when available. In the interim, incremental costs for these equipment types should be determined on a site-specific basis.

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building code, the date of installation, and whether the baseline condition is time of sale or early replacement.¹⁰⁶⁴

¹⁰⁶⁴ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Time of Sale Air-Cooled Unitary Air Conditioners Incremental Costs (\$/ton)¹⁰⁶⁵

Size Category (Cooling Capacity)	Subcategory	Incremental Cost (\$/ton)
		Installations on or After January 1, 2018
		Baseline Condition (IECC 2018)
<65,000 BTU/h	Split system	Unchanged
	Single package	Unchanged
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	\$395
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	\$151
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	\$50
≥760,000 BTU/h	Split system and single package	Unchanged

¹⁰⁶⁵ Incremental costs in this table assume CEE Tier 2 efficiency as presented in Consortium for Energy Efficiency. 2016. CEE Commercial Unitary Air-Conditioning and Heat Pumps Specification, Effective January 12, 2016. Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Time of Sale Air-Source Unitary Heat Pumps Incremental Costs (\$/ton)¹⁰⁶⁶

Size Category (Cooling Capacity)	Subcategory	Incremental Cost (\$/ton)
		On or After January 1, 2018
		Baseline Condition (Federal Standards)
<65,000 BTU/h	Split System	Unchanged
	Single Package	Unchanged
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	\$0
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	\$0
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	\$0

¹⁰⁶⁶ Incremental costs in this table assume CEE Tier 2 efficiency as presented in Consortium for Energy Efficiency. 2016. CEE Commercial Unitary Air-Conditioning and Heat Pumps Specification, Effective January 12, 2016, except for equipment $\geq 135,000$ BTU/h. For equipment $\geq 135,000$ BTU/h, CEE Tier 1 efficiencies are assumed because Tier 2 requirements are not defined for these categories. Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Early Replacement Air-Cooled Unitary Air Conditioners Costs and Deferred Replacement Credits (\$/ton)¹⁰⁶⁷

Size Category (Cooling Capacity)	Subcategory	Full Cost of Efficient Equipment (\$/ton)	Early Replacement (\$/ton) (On or After Jan,1 2018)
<65,000 BTU/h	Split system	\$1,840	\$872
	Single package	\$1,057	\$740
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	\$1,914	\$1,175
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	\$1,443	\$1,586
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	\$1,253	\$1,596
≥760,000 BTU/h	Split system and single package	\$1,271	\$5,54

¹⁰⁶⁷ Full costs of efficient equipment in this table assume CEE Tier 2 efficiency as presented in Consortium for Energy Efficiency. 2016. CEE Commercial Unitary Air-Conditioning and Heat Pumps Specification, Effective January 12, 2016. Full costs for new baseline equipment assume efficiencies for "On or After January 1, 2018" presented in table "Baseline Efficiencies by System Type and Unit Capacity" above. Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 WO017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Air-Source Unitary Heat Pumps Early Retirement Costs and Deferred Replacement Credits (\$/ton)¹⁰⁶⁸

Size Category (Cooling Capacity)	Subcategory	Full Cost of Efficient Equipment (\$/ton)	Early Replacement (\$/ton) (On or After Jan,1 2018)
<65,000 BTU/h	Split System	\$1,523	\$704
	Single Package	\$1,208	\$557
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	\$1,628	\$584
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	\$1,431	\$588
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	\$1,339	\$556

Measure Life
The measure life is assumed to be 15 years.¹⁰⁶⁹

Operation and Maintenance Impacts
n/a

Ductless Mini-Split Heat Pump (DMSHP)

Unique Measure Code(s): CI_HV_TOS_DMSHP_0519, CI_HV_EREP_DMSHP_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure relates to the installation of new ENERGY STAR rated ductless “mini-split” heat pump(s) (DMSHP). A ductless mini-split heat pump is a type of heat pump with an outdoor condensing unit connected via refrigerant line to one or more indoor evaporator coils. Ductless mini-split heat pumps deliver cooling at the same or higher efficiency as standard central AC units, but can also deliver heat. Further, since the units do not require ductwork, they avoid duct losses.

Definition of Baseline Condition

This measure assumes installation in a small commercial space.

¹⁰⁶⁸ Full costs of efficient equipment in this table assume CEE Tier 2 efficiency as presented in Consortium for Energy Efficiency. 2016. CEE Commercial Unitary Air-Conditioning and Heat Pumps Specification, Effective January 12, 2016, except for equipment $\geq 135,000$ BTU/h. For equipment $\geq 135,000$ BTU/h, CEE Tier 1 efficiencies are assumed because Tier 2 requirements are not defined for these categories. Full costs for new baseline equipment assume efficiencies for “On or After January 1, 2018” presented in table “Baseline Efficiencies by System Type and Unit Capacity” above. Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

¹⁰⁶⁹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>.

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Time of Sale or New Construction: Since the efficient unit is unducted, it is assumed that the baseline equipment will also be unducted. In such cases, or if the baseline condition for an early replacement is unknown, it is assumed that the baseline equipment is a window AC unit with a gas hot water boiler feeding hot water baseboards. The assumed baseline efficiency is that of equipment minimally compliant federal efficiency standards.

Early Replacement: The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.¹⁰⁷⁰ If the space is currently uncooled, it is assumed that the building owner would have installed cooling by other means and should therefore be treated as a lost opportunity measure with a window AC baseline.

Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified ductless mini-split heat pump, with a minimum 15 SEER, 12.0 EER, and 8.5 HSPF. If the rated efficiency of the actual unit is higher than the ENERGY STAR minimum requirements, the actual efficiency ratings should be used in the calculation.

Baseline and Efficient Levels by Unit Capacity

If the measure is a retrofit, the actual efficiencies of the baseline heating and cooling equipment should be used. If it is a market opportunity, the baseline efficiency should be selected from the tables below.

¹⁰⁷⁰ To enable improvements to this measure characterization in the future, the existing equipment types should be tracked by the program to ensure that this measure characterizes the appropriate baseline conditions.

Baseline Window AC Efficiency¹⁰⁷¹

Equipment Type	Capacity (BTU/h)	Federal Standard with louvered sides (CEER)	Federal Standard without louvered sides (CEER)
Without Reverse Cycle	< 8,000	11.0	10.0
	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 24,999	9.4	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
Casement-Only	All	9.5	
Casement-Slider	All	10.4	

Baseline Central AC Efficiency

Equipment Type	Capacity (BTU/h)	SEER	EER
Split System Air Conditioners ¹⁰⁷²	All	13	11.2

¹⁰⁷¹ Federal standards.
http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
¹⁰⁷² Federal Standard as of January 1, 2015.
http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

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Packaged Air Conditioners ¹⁰⁷³	All	14	11.8
Packaged Air Source Heat Pumps ¹⁰⁷⁴	All	14	11.8

Baseline Heating System Efficiency

Equipment Type	Efficiency Metric	Efficiency
Gas Boiler ¹⁰⁷⁵	AFUE	82%
Air Source Heat Pump – Split System ¹⁰⁷⁶	HSPF	8.2
Air Source Heat Pump - Packaged	HSPF	8.0
Electric Resistance ¹⁰⁷⁷	HSPF	3.41

Annual Energy Savings Algorithm

$$\Delta kWh_{total} = \Delta kWh_{cool} + \Delta kWh_{heat}.$$
$$\Delta kWh_{cool} = CCAP \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}.$$
$$\Delta kWh_{heat}^{1078} = HCAP \times (ELEC_{HEAT}/HSPF_{base} - 1/HSPF_{ee}) \times EFLH_{heat}.$$

Where:

$$\frac{CCAP}{SEER_{base}} = \frac{\text{Cooling capacity of DMSHP unit, in kBTU/hr.}}{SEER \text{ of baseline unit. If unknown, use } 9.8^{1079}.$$

¹⁰⁷³ Ibid.

¹⁰⁷⁴ Ibid

¹⁰⁷⁵ Federal Standards for gas boilers

¹⁰⁷⁶ Federal standards for air source heat pumps

¹⁰⁷⁷ Electric heat has a COP of 1.0. Converted into HSPF units this is approximately 3.41.

¹⁰⁷⁸ This will be negative if the baseline has non-electric heat. This is because some electricity from the DMSHP is now assumed to be used for space heating. There us a corresponding savings in fossil fuel heat.

¹⁰⁷⁹ Federal standard for typical window AC sizes with louvered sides.

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$SEER_{ee}$	=	SEER of actual DMSHP. If unknown, use ENERGYSTAR minimum of 15.
$EFLH_{cool}$	=	Full load hours for cooling equipment.
	=	If actual full load cooling hours are unknown, see table “Full Load Cooling Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load cooling hours information.
HCAP	=	Heating capacity of DMSHP unit, in kBTU/hr.
ELECHEAT	=	1 if the baseline is electric heat, 0 otherwise. If unknown, assume the baseline is a gas boiler, so ELECHEAT = 0.
$HSPF_{base}$	=	HSPF of baseline equipment. See table above. ¹⁰⁸⁰
$HSPF_{ee}$	=	HSPF of actual DMSHP. If unknown, 8.5.
$EFLH_{heat}$	=	Full load hours for heating equipment.
	=	If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = CCAP \times (1/EER_{base} - 1/EER_{ee}) \times CF.$

Where:

EER_{base}	=EER of baseline unit. If unknown, use 9.8 ¹⁰⁸¹ .
EER_{ee}	=EER of actual DMSHP. If unknown, use ENERGY STAR

¹⁰⁸⁰ If unknown, assume the baseline is a gas furnace, with no electrical savings
¹⁰⁸¹ Federal standard for typical window AC sizes with louvered sides.

minimum of 12.0.

CF_{PJM} = *PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather.*

= 0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.¹⁰⁸²

CF_{SSP} = *Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).*

= 0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.¹⁰⁸³

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$\Delta\text{MMBTU} = \text{HCAP} \times \text{EFLH}_{\text{heat}} / \text{AFUE} / 1,000$

Where:

$\text{EFLH}_{\text{heat}}$ = Full load hours for heating equipment. See table above.

AFUE = AFUE of baseline equipment. If unknown use 82%.¹⁰⁸⁴

Incremental Cost

¹⁰⁸² C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011

¹⁰⁸³ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011.

¹⁰⁸⁴ Federal standard for gas boilers.

The full installed cost of the ductless mini-split system is shown below.¹⁰⁸⁵

Capacity (kBtu/h)	Efficiency			
	13 SEER	18 SEER	21 SEER	26 SEER
9	\$2,733	\$3,078	\$3,236	\$3,460
12	\$2,803	\$3,138	\$3,407	\$3,363
18	\$3,016	\$3,374	\$3,640	N/A
24	\$3,273	\$3,874	N/A	N/A

The full installed cost of the baseline equipment is shown below.

Unit	Cost
Window AC ¹⁰⁸⁶	\$170/unit
Gas furnace ¹⁰⁸⁷	\$1,606/unit
Electric Baseboard ¹⁰⁸⁸	\$0 ¹⁰⁸⁹

If the measure is a time of sale or new construction project, subtract the costs of the baseline heating and cooling equipment from the appropriate cost of the DSMHP, as shown in the first table above. If the measure is an early replacement, use the full

¹⁰⁸⁵ Navigant, Inc. Incremental Cost Study Phase 2. January 16, 2013. Table 16.

¹⁰⁸⁶ Energy Star Calculator.

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls

¹⁰⁸⁷ Energy Star Calculator. 46% added to value to reflect labor, based on ratio of equipment to labor cost for measure EffFurn-cond-90AFUE in DEER database.

http://www.energystar.gov/buildings/sites/default/uploads/files/Furnace_Calculator.xls?8178-e52c

¹⁰⁸⁸ If existing case is electric resistance heat, assume project replaces existing functional baseboard.

¹⁰⁸⁹ A cost of \$0 for electric baseboard heat is assumed as it is likely that existing equipment would still be operable through the life of the early replacement measure.

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installed cost of the DMSHP as the incremental cost. For the purposes of cost-effectiveness screening, there can also be a deferred cost credit given at the end of the existing equipment’s remaining life to account for when the customer would have had to purchase new equipment if they had not performed the early replacement.

Measure Life

The measure life for a DSMHP is 18 years.¹⁰⁹⁰

Operation and Maintenance Impacts

n/a

¹⁰⁹⁰ GDS Associates, Inc. (2007). *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

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Variable Frequency Drive (VFD) for HVAC

Unique Measure Code(s): CI_MO_RF_VFDRIIVE_0518

Effective Date: May 2018

End Date: TBD

Measure Description

This measure defines savings associated with installing a variable frequency drive on a motor of 200 hp or less for the following HVAC applications: supply fans, return fans, exhaust fans, chilled water pumps, and heating hot water pumps. The fan or pump speed will be controlled to maintain the desired system pressure. The application must have a load that varies and proper controls (i.e., Two-way valves, VAV boxes) must be installed. Pump VFDs should be analyzed using a custom approach wherever possible given the variability of the energy and demand saving factors. Non-HVAC VFDs should be evaluated using a custom approach, and this VFD for HVAC measure is not applicable to non-HVAC applications.

Definition of Baseline Condition

The baseline condition is a motor, 200 hp or less, without a VFD control.

Definition of Efficient Condition

The efficient condition is a motor, 200 hp or less, with a VFD control.

Annual Energy Savings Algorithm¹⁰⁹¹

¹⁰⁹¹ Unless otherwise noted, savings characterization and associated parameters adopted from Del Balso, R., and K. Monsef. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications", University of Colorado, Department of Civil, Environmental and Architectural Engineering, 2013.

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HVAC Fan Applications

$$\Delta kWh = \Delta kWh_{FAN} * (1 + IE_{ENERGY})$$

$$\Delta kWh_{FAN} = kWh_{BASE} - kWh_{RETRO}$$

$$kWh_{BASE} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}} \right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{BASE})$$

$$kWh_{RET} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}} \right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{RET})$$

Where:

- ΔkWh_{FAN} = Fan-only annual energy savings.
 IE_{ENERGY} = HVAC interactive effects factor for energy
 = Assume 0%.¹⁰⁹²
 ΔkWh_{FAN} = Baseline annual energy consumption (kWh/yr).
 ΔkWh_{RETRO} = Retrofit annual energy consumption (kWh/yr).
 0.746 = Conversion factor for hp to kWh.
 HP = Nominal horsepower of controlled motor.
 = Actual.
 LF = Load Factor; Motor Load at Fan Design CFM.
 = If actual load factor is unknown, assume 65%.

¹⁰⁹² Del Balso, R., and K. Monsef, 2013 notes that the default HVAC interactive effects factor presented in the paper, 15.7%, “should not be used for actual program implementation, but such a factor should be developed and used based on a more complete set of energy modeling results for a given jurisdiction.” A value of zero should be assumed, essentially omitting interactive effects, until a jurisdiction-specific analysis can be performed.

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η_{MOTOR} = Installed nominal/nameplate motor efficiency.
= Actual efficiency.

$RHRS_{BASE}$ = Annual operating hours for fan motor based on building type.
= If actual hours are unknown, assume defaults in VFD Operating Hours by Application and Building Type table below.

%FF = Percentage of run-time spent within a given flow fraction range.
= If actual values unknown, see Default Fan Duty Cycle table below for default values.

Default Fan Duty Cycle

Flow Fraction (% of design cfm)	Percent of Time at Flow Fraction (%FF)
0% to 10%	0.0%
10% to 20%	1.0%
20% to 30%	5.5%
30% to 40%	15.5%
40% to 50%	22.0%
50% to 60%	25.0%
60% to 70%	19.0%
70% to 80%	8.5%
80% to 90%	3.0%
90% to 100%	0.5%

PLR_{BASE} = Part load ratio for a given flow fraction range based on the baseline flow control type.

PLR_{RETRO} = Part load ratio for a given flow fraction range based on the retrofit flow control type.

Part Load Ratios by Control and Fan Type and Flow Fraction (PLR)

Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Control or Bypass Damper	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Discharge Dampers	0.46	0.55	0.63	0.70	0.77	0.83	0.88	0.93	0.97	1.00
Outlet Damper, BI & Airfoil Fans	0.53	0.53	0.57	0.64	0.72	0.80	0.89	0.96	1.02	1.05
Inlet Damper Box	0.56	0.60	0.62	0.64	0.66	0.69	0.74	0.81	0.92	1.07
Inlet Guide Vane, BI & Airfoil Fans	0.53	0.56	0.57	0.59	0.60	0.62	0.67	0.74	0.85	1.00
Inlet Vane Dampers	0.38	0.40	0.42	0.44	0.48	0.53	0.60	0.70	0.83	0.99
Outlet Damper, FC Fans	0.22	0.26	0.30	0.37	0.45	0.54	0.65	0.77	0.91	1.06
Eddy Current Drives	0.17	0.20	0.25	0.32	0.41	0.51	0.63	0.76	0.90	1.04
Inlet Guide Vane, FC Fans	0.21	0.22	0.23	0.26	0.31	0.39	0.49	0.63	0.81	1.04
VFD with duct static pressure controls	0.09	0.10	0.11	0.15	0.20	0.29	0.41	0.57	0.76	1.01
VFD with low/no duct static pressure (<1" w.g.)	0.05	0.06	0.09	0.12	0.18	0.27	0.39	0.55	0.75	1.00

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HVAC Pump Applications

$$\Delta kWh = ((HP * 0.746 * LF) / \eta_{MOTOR}) * RHRS_{BASE} * ESF$$

Where:

- HP

= Nominal horsepower of controlled motor.
= Actual.
- 0.746

= Conversion factor for hp to kWh.
- LF

= Load Factor; Motor Load at Pump Design flow rate.
= If actual load factor is unknown, assume 65%.
- η_{MOTOR}

= Installed nominal/nameplate motor efficiency.
= Actual efficiency.
- $RHRS_{BASE}$

= Annual operating hours for pump motor based on building type.
= If actual hours are unknown, assume defaults in VFD Operating Hours by Application and Building Type table below.
- ESF

= Energy Savings Factor (see table “Energy and Demand Savings Factors” below).

Summer Coincident Peak kW Savings Algorithm

HVAC Fan Applications

- ΔkW

= $\Delta kW_{FAN} * (1 + IE_{DEMAND})$.
- ΔkW_{FAN}

= $\Delta kW_{BASE} - \Delta kW_{RETRO}$.
- ΔkW_{BASE}

= $(0.746 * HP * LF / \eta_{MOTOR}) * PLR_{BASE, PEAK}$.
- ΔkW_{RETRO}

= $(0.746 * HP * LF / \eta_{MOTOR}) * PLR_{RETRO, PEAK}$.

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Where:

ΔkW_{FAN} = Fan-only annual demand savings (kW).

IE_{DEMAND} = HVAC interactive effects factor for demand.
= If unknown, assume 0%.¹⁰⁹³

ΔkW_{FAN} = Baseline summer coincident peak demand (kW).

ΔkW_{RETRO} = Retrofit summer coincident peak demand (kW).

$PLR_{BASE, PEAK}$ = PLR for the average flow fraction during summer peak period for baseline flow control type (default average flow fraction during peak period = 100 %).

$PLR_{RETRO, PEAK}$ = PLR for the average flow fraction during summer peak period for retrofit flow control type (default average flow fraction during peak period = 100%).

HVAC Pump Applications

$$\Delta kW = ((HP * 0.746 * LF) / \eta_{MOTOR}) * DSF * CF.$$

Where:

DSF = Demand Savings Factor (see table “Energy and Demand Savings Factors” below).

CF = Summer Peak Coincidence Factor for measure

¹⁰⁹³ Del Balso, R., and K. Monsef, 2013 notes that the default HVAC interactive effects factor presented in the paper, 15.7%, “should not be used for actual program implementation, but such a factor should be developed and used based on a more complete set of energy modeling results for a given jurisdiction.” A value of zero should be assumed, essentially omitting interactive effects, until a jurisdiction-specific analysis can be performed.

$$= 0.55. ^{1094}$$

VFD Operating Hours by Application and Building Type (RHRS_{BASE})¹⁰⁹⁵

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Auto Related	4,056	1,878	5,376
Bakery	2,854	1,445	5,376
Banks, Financial Centers	3,748	1,767	5,376
Church	1,955	1,121	5,376
College – Cafeteria	6,376	2,713	5,376
College - Classes/Administrative	2,586	1,348	5,376
College - Dormitory	3,066	1,521	5,376
Commercial Condos	4,055	1,877	5,376
Convenience Stores	6,376	2,713	5,376
Convention Center	1,954	1,121	5,376
Court House	3,748	1,767	5,376
Dining: Bar Lounge/Leisure	4,182	1,923	5,376
Dining: Cafeteria / Fast Food	6,456	2,742	5,376
Dining: Family	4,182	1,923	5,376
Entertainment	1,952	1,120	5,376
Exercise Center	5,836	2,518	5,376
Fast Food Restaurants	6,376	2,713	5,376
Fire Station (Unmanned)	1,953	1,121	5,376
Food Stores	4,055	1,877	5,376

¹⁰⁹⁴ UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives - Pumps.

¹⁰⁹⁵ United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document - 8th Edition for 2013 Program Year. Orange, CT. For values marked with an asterisk (*), values adapted from Pennsylvania PUC. 2016. *Technical Reference Manual* and scaled based on heating degree days.

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Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Gymnasium	2,586	1,348	5,376
Hospitals	7,674	3,180	8,760*
Hospitals / Health Care	7,666	3,177	8,760*
Industrial - 1 Shift	2,857	1,446	5,376
Industrial - 2 Shift	4,730	2,120	5,376
Industrial - 3 Shift	6,631	2,805	5,376
Laundromats	4,056	1,878	5,376
Library	3,748	1,767	5,376
Light Manufacturers	2,857	1,446	5,376
Lodging (Hotels/Motels)	3,064	1,521	5,942*
Mall Concourse	4,833	2,157	5,376
Manufacturing Facility	2,857	1,446	5,376
Medical Offices	3,748	1,767	5,376
Motion Picture Theatre	1,954	1,121	5,376
Multi-Family (Common Areas)	7,665	3,177	5,376
Museum	3,748	1,767	5,376
Nursing Homes	5,840	2,520	5,428*
Office (General Office Types)	3,748	1,767	3,038*
Office/Retail	3,748	1,767	3,038*
Parking Garages & Lots	4,368	1,990	5,376
Penitentiary	5,477	2,389	5,376
Performing Arts Theatre	2,586	1,348	5,376
Police / Fire Stations (24 Hr)	7,665	3,177	5,376
Post Office	3,748	1,767	5,376
Pump Stations	1,949	1,119	5,376
Refrigerated Warehouse	2,602	1,354	0
Religious Building	1,955	1,121	5,376
Residential (Except Nursing Homes)	3,066	1,521	5,376

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Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Restaurants	4,182	1,923	5,376
Retail	4,057	1,878	2,344*
School / University	2,187	1,205	4,038*
Schools (Jr./Sr. High)	2,187	1,205	3,229*
Schools (Preschool/Elementary)	2,187	1,205	3,229*
Schools (Technical/Vocational)	2,187	1,205	3,229*
Small Services	3,750	1,768	5,376
Sports Arena	1,954	1,121	5,376
Town Hall	3,748	1,767	5,376
Transportation	6,456	2,742	5,376
Warehouse (Not Refrigerated)	2,602	1,354	5,376
Waste Water Treatment Plant	6,631	2,805	5,376
Workshop	3,750	1,768	5,376

Energy and Demand Savings Factors¹⁰⁹⁶

HVAC Pump VFD Savings Factors		
System	ESF	DSF
Chilled Water Pump	0.633	0.460
Hot Water Pump	0.652	0.000

Annual Fossil Fuel Savings Algorithm

¹⁰⁹⁶ United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document - 8th Edition for 2013 Program Year. Orange, CT; energy and demand savings constants were derived using a temperature bin spreadsheet and typical heating, cooling, and fan load profiles. Note, these values have been adjusted from the source data for remove the embedded load factor.

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n/a

Annual Water Savings Algorithm
n/a

Incremental Cost The incremental cost for this retrofit measure varies by controlled motor horsepower and whether it has bypass capability. The lifecycle NPV incremental costs for air cooled units are provided in the tables below.¹⁰⁹⁷

¹⁰⁹⁷ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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Rated Motor Horsepower (HP)	Total Installed Costs	
	With Bypass	No Bypass
2	\$ 2,178	\$ 1,811
3	\$ 2,261	\$ 1,894
4	\$ 2,344	\$ 1,977
5	\$ 2,426	\$ 2,059
7.5	\$ 2,581	\$ 2,215
10	\$ 2,737	\$ 2,370
15	\$ 4,030	\$ 3,008
20	\$ 4,432	\$ 3,410
25	\$ 4,833	\$ 3,811
30	\$ 5,235	\$ 4,213
40	\$ 6,038	\$ 5,016
50	\$ 6,842	\$ 5,820
60	\$ 8,071	\$ 7,049
75	\$ 9,043	\$ 8,021
100	\$ 10,663	\$ 9,641
200	\$ 17,143	\$ 16,121

Measure Life

The measure life is assumed to be 15 years for HVAC applications.¹⁰⁹⁸

¹⁰⁹⁸ Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

Operation and Maintenance Impacts
n/a

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Electric Chillers

Unique Measure Code: CI_HV_TOS_ELCHIL_0615, CI_HV_EREP_ELCHIL_0615
Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the installation of a new high-efficiency electric water chilling package in place of an existing chiller or a new standard efficiency chiller of the same capacity. This measure applies to time of sale, new construction, and early replacement opportunities.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2018 (IECC 2018), Table C403.3.2(7).

Early Replacement: The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.

Definition of Efficient Condition

The efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2018 (IECC 2018), Table C403.3.2(7).

Annual Energy Savings Algorithm

Time of Sale and New Construction:

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$$\Delta kWh = TONS * (IPLV_{base} - IPLV_{ee}) * HOURS.$$

Early Replacement¹⁰⁹⁹:

$$\Delta kWh \text{ for remaining life of existing unit (i.e., measure life less the age of the existing equipment):}$$
$$= TONS * (IPLV_{exist} - IPLV_{ee}) * HOURS.$$

$$\Delta kWh \text{ for remaining measure life (i.e., measure life less the remaining life of existing unit):}$$
$$= TONS * (IPLV_{base} - IPLV_{ee}) * HOURS.$$

Where:

- TONS* = Total installed capacity of the water chilling package[tons].
= Actual Installed.
- IPLV_{exist}* = Integrated Part Load Value (IPLV)¹¹⁰⁰ of the existing equipment [kW/ton].
- IPLV_{base}* = Integrated Part Load Value (IPLV) of the new baseline equipment [kW/ton].

¹⁰⁹⁹ The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

¹¹⁰⁰ Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

- = *Varies by equipment type and capacity. See “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section below.*¹¹⁰¹

IPLV_{ee}

= *Integrated Part Load Value (IPLV) of the efficient equipment [kW/ton].*

= *Actual Installed.*

HOURS

= *Full load cooling hours.*

= *If actual full load cooling hours are unknown, assume values presented in table “Full Load Hours by Location and Building Type” in the “Reference Tables” section below. Otherwise, use site specific full load cooling hours information.*
- Summer Coincident Peak kW Savings Algorithm
- Time of Sale and New Construction:
- $$\Delta kW = \text{TONS} * (\text{Full\_Loadbase} - \text{Full\_Loadee}) * CF.$$
- Early replacement:
- $$\Delta kW \text{ for remaining life of existing unit (i.e., measure life less the age of the existing equipment):}$$

$$= \text{TONS} * (\text{Full\_Loadexist} - \text{Full\_Loadee}) * CF.$$

$$\Delta kW \text{ for remaining measure life (i.e., measure life less the remaining life of existing unit):}$$
- ¹¹⁰¹ Baseline efficiencies based on International Energy Conservation Code 2018, Table C403.3.2(7) Water Chilling Packages - Efficiency Requirements
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= TONS * (Full_Loadbase - Full_Loadee) * CF.

Where:

Full_Loadexist = Full load efficiency of the existing equipment [kW/ton].

Full_Loadbase = Full load efficiency of the baseline equipment [kW/ton].

= Varies by equipment type and capacity. See “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section below¹¹⁰²

Full_Loadee = Full load efficiency of the efficient equipment.

= Actual Installed [kW/ton].

CF_{PJM} = PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather = 0.808.¹¹⁰³

CF_{SSP} = Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday). = 0.923.¹¹⁰⁴

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

¹¹⁰² Baseline efficiencies based on International Energy Conservation Code 2018, Table C403.3.2(7) Water Chilling Packages - Efficiency Requirements
¹¹⁰³ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.
¹¹⁰⁴ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

Incremental Cost

The incremental costs for time of sale chillers are shown in the tables below for time of sale and new construction scenarios.¹¹⁰⁵ Because of differences in baselines due to differing code requirements by jurisdiction, the incremental costs vary by jurisdiction. If the measure is an early replacement, the full installed cost of the efficient unit should be used as the incremental cost and determined on a site-specific basis. For the purposes of cost-effectiveness screening, there is also a deferred cost credit given at the end of the existing equipment's remaining life to account for when the customer would have had to purchase new equipment if they had not performed the early replacement.

Air-Cooled Chiller Incremental Costs (\$/Ton)

Capacity (Tons)	Baseline EER	Efficient EER			
		9.9	10.2	10.52	10.7
50	10.1	N/A	\$55	\$146	\$207
100	10.1	N/A	\$27	\$73	\$104
150	10.1	N/A	\$18	\$49	\$69
200	10.1	N/A	\$14	\$ 37	\$52
400	10.1	N/A	\$7	\$ 18	\$26

¹¹⁰⁵ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

Water-Cooled Scroll/Screw Chiller Incremental Costs (\$/Ton)

Capacity (Tons)	Baseline kW/ton	Efficient kW/ton			
		0.72	0.68	0.64	0.60
50	0.75	\$156	\$363	N/A	N/A
100	0.72	\$0	\$104	N/A	N/A
150	0.66	N/A	N/A	N/A	N/A
200	0.66	N/A	N/A	\$26	\$78
400	0.61	N/A	N/A	N/A	\$6

Water-Cooled Centrifugal Chiller Incremental Costs (\$/Ton)

Capacity (Tons)	Baseline kW/ton	Efficient kW/ton		
		0.6	0.58	0.54
100	0.61	\$26	\$78	\$181
150	0.61	\$17	\$52	\$121
200	0.61	\$13	\$39	\$91
300	0.56	N/A	N/A	\$17
600	0.56	N/A	N/A	\$9

Measure Life

The measure life is assumed to be 23 years¹¹⁰⁶.

¹¹⁰⁶ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "[http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf](http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf)"

Operation and Maintenance Impacts
n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency¹¹⁰⁷

Equipment Type	Size Category	Units	Path A ^a		Path B ^a	
			Full Load	IPLV	Full Load	IPLV
Air-Cooled Chillers	<150 tons	EER	≥10.100	≥13.700	≥9.700	≥15.800
	≥150 tons	EER	≥10.100	≥14.000	≥9.700	≥16.100
Water Cooled, Electrically Operated, Positive Displacement	<75 tons	kW/ton	≤0.750	≤0.600	≤0.780	≤0.500
	≥75 tons and <150 tons	kW/ton	≤0.720	≤0.560	≤0.750	≤0.490
	≥150 tons and <300 tons	kW/ton	≤0.660	≤0.540	≤0.680	≤0.440
	≥300 tons and <600 tons	kW/ton	≤0.610	≤0.520	≤0.625	≤0.410
	≥600 tons	kW/ton	≤0.560	≤0.500	≤0.585	≤0.380
Water Cooled, Electrically Operated, Centrifugal	<150 tons	kW/ton	≤0.610	≤0.550	≤0.695	≤0.440
	≥150 tons and <300 tons	kW/ton	≤0.610	≤0.550	≤0.635	≤0.400
	≥300 tons and <400 tons	kW/ton	≤0.560	≤0.520	≤0.595	≤0.390
	≥400 tons and <600 tons	kW/ton	≤0.560	≤0.500	≤0.585	≤0.380
	≥600 tons	kW/ton	≤0.560	≤0.500	≤0.585	≤0.380

a. Compliance with IECC 2018 can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.

¹¹⁰⁷ Baseline efficiencies based on International Energy Conservation Code 2018, Table C403.3.2(7) Water Chilling Package - Efficiency Requirements.

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Full Load Cooling Hours by Location and Building Type (HOURS)¹¹⁰⁸

Space and/or Building Type	Dover, DE	Wilmington, DE
Education - Community College	737	725
Education - Secondary School	366	360
Education - University	809	796
Health/Medical - Hospital	1,557	1,533
Health/Medical - Nursing Home	596	586
Lodging - Hotel	1,787	1,758
Manufacturing – Bio Tech/High Tech	804	791
Office - Large	598	589
Office - Small	554	545
Retail - Multistory Large	920	906

¹¹⁰⁸ Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook – Fundamentals. See <http://www.neep.org/file/5550/download?token=6THHJ4D7> for calculations.

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Gas Boiler

Unique Measure Code: CI_HV_TOS_GASBLR_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of a high efficiency gas boiler in the place of a standard efficiency gas boiler. This measure applies to time of sale and new construction opportunities.

Definition of Baseline Condition

Time of Sale: The baseline condition is a gas boiler with efficiency equal to the current federal standards. See the “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section.

Definition of Efficient Condition

The efficient condition is a high-efficiency gas boiler of at least 90% AFUE for units <300 kBTU/h and 94% E_t for units >300 kBTU/h. See the “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta\text{MMBTU} = \text{CAP} * \text{HOURS} * (1/\text{EFF}_{\text{base}} - 1/\text{EFF}_{\text{ee}}) / 1,000,000.$$

- Where:
- CAP** = Equipment capacity [BTU/h].
= Actual Installed.
 - HOURS** = Full Load Heating Hours.
= See “Full Load Heating Hours by Location and Building Type” table in the “Reference Tables” section below.¹¹⁰⁹
 - EFF_{base}** = The efficiency of the baseline equipment; Can be expressed as thermal efficiency (*E_t*), combustion efficiency (*E_c*), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.
= For time of sale: See “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section below¹¹¹⁰ equipment.
 - EFF_{ee}** = The efficiency of the efficient equipment; Can be expressed as thermal efficiency (*E_t*), combustion efficiency (*E_c*), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.
= Actual Installed.
 - 1,000,000** = BTU/MMBTU unit conversion factor.

¹¹⁰⁹ HOURS estimates developed from data presented in “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs”, TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using heating degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

¹¹¹⁰ Baseline efficiencies based on the Energy Independence and Security Act of 2007 and the International Energy Conservation Code 2018, Table C403.3.2(5) Minimum Efficiency Requirements: Gas- and Oil-fired Boilers.

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental cost for this time of sale measure varies by size category and efficiency level. See the “Time of Sale Incremental Costs” table in the “Reference Tables” section below.

Measure Life
The measure life is assumed to be 20 years¹¹¹¹.

Operation and Maintenance Impacts
n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency¹¹¹²

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency
Boilers, Gas-fired	<300,000 BTU/h	Hot water	82% AFUE
		Steam	80% AFUE
		Hot water	80% E _t

¹¹¹¹ Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.
¹¹¹² Baseline efficiencies based on current federal standards (http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf) and International Energy Conservation Code 2018, Table C403.3.2(5) Minimum Efficiency Requirements: Gas- and Oil-fired Boilers.

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency
	>=300,000 BTU/h and <=2,500,000 BTU/h	Steam – all, except natural draft	79.0% E _t
		Steam – natural draft	77.0% E _t
	>2,500,000 BTU/h	Hot water	82.0% E _c
		Steam – all, except natural draft	79.0% E _t
		Steam – natural draft	77.0% E _t

Time of Sale Incremental Costs¹¹¹³

Size Category (kBtu/h)	Efficiency	Incremental Cost
<300 (kBtu/h) Gas Hot Water and Steam Boilers	90% AFUE	\$469
	92% AFUE	\$513
	95% AFUE	\$643
	98%AFUE	\$789
Gas-Fired Hot Water Commercial Packaged Boiler ≥300 kBtu/h and ≤2,500 kBtu/h	95% E _t	\$17,288
	99% E _t	\$20,349

¹¹¹³ For units <300 kBtu/h, Costs were derived the Residential Furnace Technical support document, 2016 and adjusted for inflation to represent 2017 dollars
For Units, Greater than 300 BTU/h sources Incremental Cost values are derived from the Commercial Packaged TSD.
<https://www.regulations.gov/document?D=EERE-2013-BT-STD-0030-0083>

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Size Category (kBtu/h)	Efficiency	Incremental Cost
Gas-Fired Hot Water Commercial Packaged Boiler ≥2,500,000 kBtu/h and 10,000,000≤kBtu/h	95% E _t	\$70,860
	99% E _t	\$78,777

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Full Load Heating Hours by Location and Building Type (HOURS_{HEAT})¹¹¹⁴

Space and/or Building Type	Dover, DE	Wilmington, DE
Assembly	1,114	1,150
Education - Community College	713	736
Education - Primary School	668	689
Education - Relocatable Classroom	647	668
Education - Secondary School	719	742
Education - University	530	546
Grocery	984	1,015
Health/Medical - Hospital	214	221
Health/Medical - Nursing Home	932	962
Lodging - Hotel	2,242	2,313
Manufacturing – Bio Tech/High Tech	146	151
Manufacturing – 1 Shift/Light Industrial	585	603
Multi-Family (Common Areas)	256	264
Office - Large	221	228
Office - Small	440	454
Restaurant - Fast-Food	1,226	1,265
Restaurant - Sit-Down	1,131	1,167
Retail - Multistory Large	591	609
Retail - Single-Story Large	739	762
Retail - Small	622	642
Storage - Conditioned	854	881
Warehouse - Refrigerated	342	353

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¹¹¹⁴ Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook – Fundamentals. See <http://www.neep.org/file/5550/download?token=6THHJ4D7> for calculations.

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Gas Furnace

Unique Measure Code: CI_HV_TOS_GASFUR_0615

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to the installation of a high efficiency gas furnace with capacity less than 225,000 BTU/h with an electronically commutated fan motor (ECM) in the place of a standard efficiency gas furnace. This measure applies to time of sale and new construction opportunities.

Definition of Baseline Condition

Time of Sale: The baseline condition is a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 80% with a standard efficiency furnace fan.

Definition of Efficient Condition

The efficient condition is a high-efficiency gas furnace with an AFUE of 90% or higher. This characterization only applies to furnaces with capacities less than 225,000 BTU/h with an electronically commutated fan motor (ECM).

Annual Energy Savings Algorithm¹¹¹⁵

$$\Delta \text{kWh} = 733 \text{ kWh}.^{1116}$$

¹¹¹⁵ Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

¹¹¹⁶ Deemed savings from ECM Furnace Impact Assessment Report. Prepared by PA Consulting for the Wisconsin Public Service Commission 2009. Based on in depth engineering analysis and interviews taking into account the latest research on behavioral aspects of furnace fan use.

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Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0.19 \text{ kW}.$ ¹¹¹⁷

Annual Fossil Fuel Savings Algorithm

$\Delta \text{MMBTU} = \text{CAP} * \text{HOURS} * ((1/\text{AFUE}_{\text{base}}) - (1/\text{AFUE}_{\text{ee}})) / 1,000,000.$

Where:

- CAP

= Capacity of the high-efficiency equipment [BTU/h].
= Actual Installed.
- HOURS

= Full Load Heating Hours
= See “Full Load Heating Hours by Location and Building Type”
table in the “Reference Tables” section below.¹¹¹⁸
- AFUE_{base}

= Annual Fuel Utilization Efficiency of the baseline equipment.
= For time of sale: 0.80.¹¹¹⁹
- AFUE_{ee}

= Annual Fuel Utilization Efficiency of the efficient equipment.
= Actual Installed.
- 1,000,000

= BTU/MMBTU unit conversion factor.

¹¹¹⁷ Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.

¹¹¹⁸ HOURS estimates developed from data presented in “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs”, TecMarket Works, October 15, 2010, adjusted to Mid-Atlantic region using heating degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

¹¹¹⁹ Baseline efficiencies based on International Energy Conservation Code 2018, Table C403.3.2(4) Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements.

Annual Water Savings Algorithm

n/a

Incremental Cost

The time of sale incremental cost for this time of sale measure is provided below.¹¹²⁰

Efficiency of Furnace (AFUE)	Incremental Cost
90%	\$392
92%	\$429
95%	\$537
98%	\$659

Measure Life

The measure life is assumed to be 18 years¹¹²¹.

Operation and Maintenance Impacts

n/a

¹¹²⁰ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Adapted from Department of Energy, Residential Furnaces and Boilers Final Rule Technical Support Document, 2016, Table 8-2-16. <https://www.regulations.gov/document?D=EERE-2014-BT-STD-0031-0217>. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

¹¹²¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf"

Reference Tables

Full Load Heating Hours by Location and Building Type (HOURS_{HEAT})¹¹²²

Space and/or Building Type	Dover, DE	Wilmington, DE
Assembly	1,114	1,150
Education - Community College	713	736
Education - Primary School	668	689
Education - Relocatable Classroom	647	668
Education - Secondary School	719	742
Education - University	530	546
Grocery	984	1,015
Health/Medical - Hospital	214	221
Health/Medical - Nursing Home	932	962
Lodging - Hotel	2,242	2,313
Manufacturing – Bio Tech/High Tech	146	151
Manufacturing – 1 Shift/Light Industrial	585	603
Multi-Family (Common Areas)	256	264
Office - Large	221	228
Office - Small	440	454

¹¹²² Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook – Fundamentals. See <http://www.neep.org/file/5550/download?token=6THHJ4D7> for calculations.

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Space and/or Building Type	Dover, DE	Wilmington, DE
Restaurant - Fast-Food	1,226	1,265
Restaurant - Sit-Down	1,131	1,167
Retail - Multistory Large	591	609
Retail - Single-Story Large	739	762
Retail - Small	622	642
Storage - Conditioned	854	881
Warehouse - Refrigerated	342	353

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Dual Enthalpy Economizer

Unique Measure Code: CI_HV_RF_DEECON_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure involves the installation of a dual enthalpy economizer to provide free cooling during the appropriate ambient conditions. Enthalpy refers to the total heat content of the air. A dual enthalpy economizer uses two sensors — one measuring return air enthalpy and one measuring outdoor air enthalpy. Dampers are modulated for optimum and lowest enthalpy to be used for cooling. This measure applies only to retrofits.

Definition of Baseline Condition

The baseline condition is the existing HVAC system with no economizer.

Definition of Efficient Condition

The efficient condition is the HVAC system with dual enthalpy controlled economizer.

Annual Energy Savings Algorithm

$$\Delta kWh = TONS * SF$$

Where:

TONS = Actual Installed.
SF = Savings factor for the installation of dual enthalpy economizer control [kWh/ton].

= See “Savings Factors” table in “Reference Tables” section below.¹¹²³

Summer Coincident Peak kW Savings Algorithm
 $\Delta kW = 0 \text{ kW}$.¹¹²⁴

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental costs for this retrofit measure are presented in the “Dual Enthalpy Economizer Incremental Costs” table below.

Dual Enthalpy Economizer Incremental Costs¹¹²⁵

HVAC System Capacity (Tons)	Incremental Cost
5	\$943
15	\$1,510

¹¹²³ kWh/ton savings from “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs”, TecMarket Works, October 15, 2010, scaled based on enthalpy data from New York City and Mid-Atlantic cities from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

¹¹²⁴ Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

¹¹²⁵ Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

25	\$2,077
40	\$2,927
70	\$4,628

Measure Life

The measure life is assumed to be 10 years¹¹²⁶.

Operation and Maintenance Impacts

n/a

¹¹²⁶ General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

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Reference Tables

Savings Factors¹¹²⁷

Savings Factors (kWh/ton)	Dover, DE	Wilmington, DE
Assembly	26	22
Big Box Retail	58	50
Fast Food	37	32
Full Service Restaurant	29	25
Light Industrial	24	21
Primary School	40	34
Small Office	58	50
Small Retail	58	50
Religious	6	5
Warehouse	2	2
Other	58	50

¹¹²⁷ kWh/ton savings from NY Standard Approach Model, with scaling factors based on enthalpy data from NYC and Mid-Atlantic cities. Note: Values for Big Box Retail, Small Office, and Small Retail are anomalously high and have been set equal to the “Other” building type for conservatism based on discussion with the Mid-Atlantic TRM Stakeholder Group.

AC Tune-Up

Unique Measure Code(s): CI_HV_RF_ACTUNE_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure is for a “tune-up” for a commercial central AC. This measure only applies to residential-style central AC systems of 5.4 tons (65,000 BTU/h) or less. Tune-ups for larger units, including units with variable air volume and air handling units, should be treated as custom measures. A recent California evaluation suggests that tune-ups on these larger systems may be better handled by breaking up the overall tune-up into a series of specific activities performed – for example, refrigerant charge correction, economizer repair, leak sealing, etc.¹¹²⁸ For smaller units, tuning measures may include:

- Refrigerant charge correction
- Air flow adjustments
- Cleaning the condensate drain line
- Clean and straighten coils and fans
- Replace air filter
- Repair damaged insulation

Definition of Baseline Condition

¹¹²⁸ California Public Utilities Commission. *HVAC Impact Evaluation Final Report*. January 28, 2014.

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The baseline condition is a pre-tune-up air conditioner. Where possible, spot measurements should be used to estimate the baseline EER. An HVAC system is eligible for a tune-up once every five years.

Definition of Efficient Condition

The efficient condition is a post-tune-up air conditioner. Where possible, spot measurements should be used to estimate the EER post-tune-up.

Annual Energy Savings Algorithm

$$\Delta kWh = CCAP \times EFLH \times 1/SEER_{pre} \times \%_{impr}.$$

Where:

- CCAP

SEER_{pre}

EFLH

%_{impr}
- = Cooling capacity of existing AC unit, in kBTU/hr.

= SEER of actual unit, before the tune-up. If testing is not done on the baseline condition, use the nameplate SEER.

= Full load hours for cooling equipment.

= If actual full load cooling hours are unknown, see table “Full Load Cooling Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load cooling hours information.

= Percent improvement based on measured EERs pre- and post-tune-up. Calculated as (EER_{post} – EER_{pre})/EER_{post}, where subscripts “pre” and “post” refer to the EER before and after the tune-up, respectively. If onsite testing data is not available, assume %_{impr} = 0.05.¹¹²⁹

¹¹²⁹ Energy Center of Wisconsin, May 2008; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.”

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = CCAP \times 1/EER_{pre} \times \%_{impr} \times CF.$$

Where:

- CCAP = Cooling capacity of DMSHP unit, in kBTU/hr.
- EER_{pre} = EER of actual unit, before the tune-up. If testing is not done on the baseline condition, use the nameplate EER.
- %_{impr} = Percent improvement based on measured EERs pre and post tune-up. Calculated as (EER_{post} – EER_{pre})/EER_{post}. If onsite testing data is not available, assumed %_{impr} = 0.05.¹¹³⁰
- CF_{PJM} = PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather. = 0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.¹¹³¹
- CF_{SSP} = Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday) = 0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.¹¹³²

Annual Fossil Fuel Savings Algorithm

n/a

¹¹³⁰ Energy Center of Wisconsin, May 2008; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.”

¹¹³¹ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011

¹¹³² C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011

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Incremental Cost

Use the actual cost of the tune-up. If this is unknown, use a default of \$35/ton¹¹³³.

Measure Life

The measure life for an AC tune-up is 5 years.¹¹³⁴

Operation and Maintenance Impacts

n/a

¹¹³³ Illinois Statewide Technical Reference Manual for Energy Efficiency Version 4.0 Final February 24 2015

¹¹³⁴ GDS Associates, Inc. (2007). *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

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Smart Thermostat

Unique Measure Code(s): CI_ HV_TOS_SMTHRM_0518, CI_ HV_RF_SMTHRM_0518

Effective Date: May 2018

End Date: TBD

Measure Description

The Smart Thermostat measure involves the replacement of a manually operated or conventional programmable thermostat with a “smart” thermostat (defined below). This measure only applies to thermostats that control central A/C, heat pump, furnace, or rooftop units (RTUs) with capacity up to 5.42 tons (65,000 BTU/h). Thermostats for larger systems should be treated as custom measures. This measure may be a time of sale, retrofit, or new construction measure.

Definition of Baseline Condition

Retrofit: As a retrofit measure, the baseline equipment is the in-situ manually operated or properly programmed thermostat that was replaced, or an assumed (defaulted) mix of these two.

Time of Sale or New Construction: The baseline condition is a programmable thermostat meeting minimum efficiency standards as presented in the 2018 International Energy Conservation Code (IECC 2018).

Definition of Efficient Condition

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The efficient condition is a smart thermostat that has earned ENERGY STAR certification¹¹³⁵ or has the following product requirements¹¹³⁶:

1. Automatic scheduling
2. Occupancy sensing (set “on” as a default)
3. For homes with a heat pump, smart thermostats must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.
4. Ability to adjust settings remotely via a smart phone or online the absence of connectivity to the connected thermostat (CT) service provider, retain the ability for residents to locally:
 - a. view the room temperature,
 - b. view and adjust the set temperature, and
 - c. switch between off, heating and cooling.
5. Have a static temperature accuracy $\leq \pm 2.0$ °F
6. Have network standby average power consumption of ≤ 3.0 W average (Includes all equipment necessary to establish connectivity to the CT service provider’s cloud, except those that can reasonably be expected to be present in the home, such as Wi-Fi routers and smart phones.)
7. Enter network standby after ≤ 5.0 minutes from user interaction (on device, remote or occupancy detection)

¹¹³⁵ ENERGY STAR’s qualified products list for smart thermostats:

<https://data.energystar.gov/dataset/ENERGY-STAR-Certified-Connected-Thermostats/7p2p-wkbf>

¹¹³⁶ ENERGY STAR Smart Thermostat Specification, from which most requirements based:

https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0_0.pdf

8. The following capabilities may be enabled through the CT device, CT service or any combination of the two. The CT product shall maintain these capabilities through subsequent firmware and software changes.
- Ability for consumers to set and modify a schedule.
 - Provision of feedback to occupants about the energy impact of their choice of settings.
 - Ability for consumers to access information relevant to their HVAC energy consumption, e.g. HVAC run time.

Annual Energy Savings Algorithm

As smart thermostats are control technologies, when possible, heating and cooling savings should be calculated based on data from installed thermostats.¹¹³⁷ Otherwise, cooling savings should only be claimed for buildings with central air conditioning. Heating savings may be claimed for buildings with electric resistance, heat pump, or non-electric heating.

$$\begin{aligned}\Delta \text{kWh} &= \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}} \\ \Delta \text{kWh}_{\text{cooling}} &= \text{CCAP} \times \text{HOURS}_{\text{cool}} \times 1/\text{SEER} \times \text{ElecCool\_Saving\_}\% \\ \Delta \text{kWh}_{\text{heating}} &= \text{HCAP}_{\text{elec}} \times \text{HOURS}_{\text{heat}} \times 1/\text{HSPF} \times \text{ElecHeat\_Saving\_}\% \\ \Delta \text{MMBTU} &= \text{HCAP}_{\text{fuel}} \times \text{HOURS}_{\text{heat}} \times 1/\text{AFUE} \times \text{FuelHeat\_Saving\_}\%\end{aligned}$$

Where:

¹¹³⁷ NEEP has developed a Guidance Document detailing methodology to claim savings from smart thermostats, available here: <http://www.neep.org/claiming-savings-smart-thermostats-guidance-document>. This guidance uses the metric developed for the ENERGY STAR certification to develop geographically and temporally specific savings averages for program claims. These calculated savings numbers are expected to be more accurate and potentially yield higher level of savings than the estimates provided in the TRM.

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CCAP	= Cooling capacity of existing AC unit, in kBTU/hr.
HOURS _{cool}	= Full load hours for cooling equipment. See table “Full Load Cooling Hours by Location and Building Type” in Appendix F.
SEER	= SEER of controlled unit. If unknown use current energy code requirements for mechanical cooling efficiency.
ElecCool_Saving_%	= Electrical cooling percent savings from thermostat relative to baseline control. If baseline thermostat type is known, see table “Savings Factors for Smart Thermostats by Baseline Technology” below. If baseline thermostat type is unknown, ElecCool_Savings_% = 4%.
HCAP _{elec}	= Heating capacity of existing heat pump or electric resistance unit, in kBTU/hr.
HOURS _{heat}	= Full load hours for heating equipment. See table “Full Load Heating Hours by Location and Building Type” in Appendix F.
HSPF	= HSPF of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency.
ElecHeat_Saving_%	= Electrical heating percent savings from thermostat relative to baseline control. If baseline thermostat type is known, see table “Savings Factors for Smart Thermostats by Baseline Technology” below. If baseline thermostat type is unknown, ElecHeat_Savings_% = 3%.
HCAP _{fuel}	= Heating capacity of existing furnace unit, in MMBTU/hr.
AFUE	= AFUE of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency.
FuelHeat_Saving_%	= Heating fuel percent savings from thermostat relative to baseline control. If baseline thermostat type is known, see table “Savings Factors for Smart Thermostats by Baseline

Technology” below. If baseline thermostat type is unknown, FuelHeat_Savings_% = 3.5%.

Savings Factors for Smart Thermostats by Baseline Technology

Fuel and Function	Baseline Technology	
	Manual Thermostat ¹¹³⁸	Programmable Thermostat ¹¹³⁹
Savings factor for electric cooling, ElecCool_Saving_%	5%	3%
Savings factor for electric heating, ElecHeat_Saving_%	4%	2%
Savings factor for fuel heating, FuelHeat_Saving_%	5%	2%

Summer Coincident Peak kW Savings Algorithm

¹¹³⁸ The savings percentages claimed for manual thermostats include the savings associated with upgrading from manual thermostats to programmable thermostats, which a 2015 MEMD study reported as about 3% savings for gas customers and 2% savings for electric customers. http://www.michigan.gov/documents/mpsc/CI_Programmable_TStats_MEMD_6_15_15_491808_7.pdf

¹¹³⁹ Relative to a programmable thermostat, smart thermostats have savings opportunities available from a “smart recovery” function, which enables users to set the time they would like the building to reach a temperature as opposed to setting a time that the unit should start operating. Savings are also available from improved error detection and from locking out building occupants’ ability to override programmed schedules. Individual case studies have demonstrated savings in a variety of small commercial applications, but large-scale evaluations of smart thermostat savings have so far been limited to thermostats installed in residential applications. CLEAResult’s “Guide to Smart Thermostats” reports the ranges of savings measured in recent *residential* evaluations, relative to a baseline that blended programmable and manual thermostats: 10-13% for gas savings; 14-18% for electric cooling savings; and 6-13% for electric heating savings. <https://www.clearesult.com/insights/whitepapers/guide-to-smart-thermostats/>

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The smart thermostat measure as defined here (i.e., without a corresponding demand reduction program) is assumed to have no demand savings. Smart thermostats with a demand response program added on top may generate significant demand savings, but those are not quantified as part of this measure.

Annual Water Savings Algorithm

n/a

Incremental Cost

If the costs are not known, then the incremental cost for a time of sale replacement is assumed to be \$154¹¹⁴⁰ and the incremental cost for a retrofit replacement is assumed to be \$208.¹¹⁴¹ Installation labor cost of \$50 for labor should be added to the assumed incremental cost.

Measure Life

¹¹⁴⁰ From NEEP's 2016 Incremental Cost Study: <http://www.neep.org/incremental-cost-emerging-technology-0>, table 3-13 found range of incremental costs to be \$80-195 (with baseline as \$54 and using Nest/Ecobee at \$249). NEEP's more recent list of home energy management systems products (<http://neep.org/initiatives/high-efficiency-products/home-energy-management-systems>) shows a straight average of 68 products at \$210 for the cost of the smart thermostat, bringing the incremental cost assuming \$54 for baseline down to \$154.

¹¹⁴¹ From NEEP's 2016 Incremental Cost Study: <http://www.neep.org/incremental-cost-emerging-technology-0>, table 3-13 found range of incremental costs to be \$80-195 (with baseline as \$54 and using Nest/Ecobee at \$249). NEEP's more recent list of home energy management systems products (<http://neep.org/initiatives/high-efficiency-products/home-energy-management-systems>) shows a straight average of 68 products at \$210 for the cost of the smart thermostat, bringing the incremental cost assuming \$54 for baseline down to \$154. Most of the models cited in the

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The measure life is assumed to be 7.5 years.¹¹⁴²

Operation and Maintenance Impacts

n/a

¹¹⁴² Based on professional judgment of TRM technical team. EULs observed for residential applications include: 11 years in AR TRM and 10 years in IL TRM, both of which are based on programmable thermostat EULs. CA workpapers conclude 3-year EUL using persistence modeling. RTF concludes a 5-year EUL based on CA workpapers and concerns that there is little basis for assuming long-time persistence of savings, considering past challenges with manual overrides and “know-how” needed to use wifi-connected devices, including communicating hardware and software downloading. For discussion, see Northwest Regional Technical Forum April 2017. <https://nwcouncil.box.com/v/ResConnectedTstatsv1-2>

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Variable Refrigerant Flow (VRF) Heat Pump Systems

Unique Measure Code(s): CI_HV_TOS_VRFHP_0619,
CI_HV_EREP_VRFHP_0619, CI_HV_NC_VRFHP_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure relates to the installation of new high efficiency variable refrigerant flow (VRF) heat pump(s) also known as variable refrigerant volume (VRV). A VRF system is a type of heat pump with one outdoor condensing unit circulating refrigerant to multiple indoor evaporator units. A DC inverter in the compressor allows for variable motor speed which in turn provides variable refrigerant flow. VRF systems deliver cooling and heating at higher efficiency than traditional air-source heat pumps. Because the energy transported to and from zones is through piped refrigerant and not ductwork, VRF avoid ductwork transport losses to and from zones. Some units can provide heating and cooling to different zones simultaneously, using waste heat from cooling one or more zones to heat others when possible. This measure does not include that heat recovery capability, though installations achieving additional savings through heat recovery are encouraged to claim savings through custom site-specific means.

Definition of Baseline Condition

Time of Sale or New Construction¹¹⁴³: For New Construction, the baseline will be a minimally compliant VRF system. For Time of Sale, the baseline will depend on if there is a pre-existing HVAC system. If there is a pre-

¹¹⁴³ In new construction, since VRF systems are “ductless” the baseline should also be ductless, which is why a VRF system is chosen for the baseline.

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existing system, the baseline will be a system of the same type with code minimum efficiency. If there is no pre-existing cooling system or the system is unknown, then the baseline system will be a minimally compliant VRF system. Minimally compliant is determined by the local energy code or federal efficiency standards, whichever has the higher efficiency.

Early Replacement: The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline will be a system of the same type with code minimum efficiency for the remainder of the measure life.¹¹⁴⁴ If the space is currently uncooled and the VRF adds cooling capability, the project will be considered new construction, with a new construction baseline.

Definition of Efficient Condition

The efficient equipment is a high-efficiency VRF system meeting or exceeding CEE Tier 1 efficiency levels. Savings will be calculated using actual equipment specifications.

Baseline and Efficient Levels by Unit Capacity

If the measure is an early replacement, the actual efficiencies of the baseline heating and cooling equipment should be used. If it is a time of sale, the baseline efficiency should be selected from the tables below.

System Efficiency

¹¹⁴⁴ To enable improvements to this measure characterization in the future, the existing equipment types should be tracked by the program to ensure that this measure characterizes the appropriate baseline conditions.

Equipment Type	Capacity (Btu/h)	Code Minimum ¹¹⁴⁵	Minimum Qualifying Efficiency ¹¹⁴⁶
VRF - air cooled (cooling mode)	< 65,000 Btu/h	13.0 SEER 11.2 EER	15.0 SEER 12.5 EER
	65,000 ≤ Btu/h < 135,000	14.6 IEER 11.0 EER	14.6 IEER 11.3 EER
	135,000 ≤ Btu/h < 240,000	13.9 IEER 10.6 EER	13.9 IEER 10.9 EER
	≥ 240,000 Btu/h	12.7 IEER 9.5 EER	12.7 IEER 10.3 EER
VRF - air cooled (heating mode)	< 65,000 Btu/h (cooling capacity)	7.7 HSPF	8.5 HSPF
	65,000 ≤ Btu/h < 135,000 (cooling capacity)	47°F db / 43°F wb outdoor Air 3.3 COP _H	3.4 COP
		17°F db / 15°F wb outdoor Air 2.25 COP _H	2.4 COP
	≥ 135,000 Btu/h	47°F db / 43°F wb outdoor Air 3.2 COP _H	3.2 COP

¹¹⁴⁵ ASHRAE 90.1 2013, Table 6.8.1-10.¹¹⁴⁶ CEE Tier 1 efficiencies. Where ASHRAE 90.1 requirements are more stringent than CEE Tier 1 efficiencies, ASHRAE 90.1 efficiencies assumed.https://library.cee1.org/system/files/library/7559/Appendix_B_2019_CEE_ComACHP_Unitary_Spec.pdf

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Equipment Type	Capacity (Btu/h)	Code Minimum ¹¹⁴⁵	Minimum Qualifying Efficiency ¹¹⁴⁶
	(cooling capacity)	17° F db / 15° F wb outdoor Air 2.05 COP _H	2.1 COP
VRF - water cooled (cooling mode)	< 65,000 Btu/h (cooling capacity)	12.0 EER 16.0 IEER	14.0 EER
	65,000 ≤ Btu/h < 135,000 (cooling capacity)	12.0 EER 16.0 IEER	14.0 EER
	≥ 135,000 Btu/h (cooling capacity)	10.0 EER 14.0 IEER	12.0 EER
VRF - water cooled (heating mode)	< 65,000 Btu/h (cooling capacity)	4.3 COP _H	4.6 COP
	65,000 ≤ 135,000 Btu/h (cooling capacity)	4.3 COP _H	4.6 COP
	≥ 135,000 Btu/h (cooling capacity)	4.0 COP _H	4.3 EER

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Annual Energy Savings Algorithm

$$\begin{aligned}\Delta \text{kWh}_{\text{total}} &= \Delta \text{kWh}_{\text{cool}} + \Delta \text{kWh}_{\text{heat}}. \\ \Delta \text{kWh}_{\text{cool}} &= (\text{BTU}/h_{\text{cool}}/1000) * (1/\text{CEF}_{\text{base}} - 1/\text{CEF}_{\text{ee}}) * \text{EFLH}_{\text{cool}}. \\ \Delta \text{kWh}_{\text{heat}}^{1147} &= (\text{ELECHEAT} * \text{BTU}/h_{\text{heat}} / \text{HEF}_{\text{base}} - \text{BTU}/h_{\text{heat}} / \text{HEF}_{\text{ee}}) / \\ &\quad \text{HU} * \text{EFLH}_{\text{heat}}.\end{aligned}$$

Where:

$$\begin{aligned}\text{BTU}/h_{\text{cool}} &= \text{Cooling capacity of VRF system, in BTU/hr.} \\ 1000 &= \text{Btu/hr to kBTU/hr conversion factor} \\ \text{CEF}_{\text{base}} &= \text{Baseline Cooling Efficiency Factor. SEER if } \text{BTU}/h_{\text{cool}} < 65,000 \text{ Btu/hr. IEER if } \text{BTU}/h_{\text{cool}} \geq 65,000 \text{ Btu/hr.} \\ &\quad - \text{If early replacement, } \text{CEF}_{\text{base}} \text{ will be the efficiency of the existing unit for the Remaining Useful Life (RUL). At the end of its RUL, } \text{CEF}_{\text{base}} \text{ becomes code minimum. New Construction and Time of Sale always use code minimum.} \\ &\quad - \text{If early replacement and prior unit's SEER or IEER is unavailable, use EER for savings calculations. If EER is also unavailable, use code minimum SEER or IEER as appropriate.} \\ \text{CEF}_{\text{ee}} &= \text{Cooling Efficiency Factor of installed VRF system. SEER if } \text{BTU}/h_{\text{cool}} < 65,000 \text{ Btu/hr. IEER if } \text{BTU}/h_{\text{cool}} \geq 65,000 \text{ Btu/hr.}\end{aligned}$$

¹¹⁴⁷ This will be negative if the baseline has non-electric heat. This is because some electricity from the VRF system is now assumed to be used for space heating. There is a corresponding savings in fossil fuel heat.

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- If early replacement and baseline SEER or IEER is unavailable, and baseline EER is used, use efficient EER as well.
- $EFLH_{cool}$ = Full load hours for cooling equipment.
= If actual full load cooling hours are unknown, see table “Full Load Cooling Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load cooling hours information.
- BTU/h_{heat} = Heating capacity of VRF unit, in BTU/hr.
 $ELEC_{HEAT}$ = 1 if the baseline heating fuel is electric. 0 if fossil fuel.
- HEF_{base} = Heating Efficiency Factor of baseline equipment.
HSPF if $BTU/h_{cool} < 65,000$ BTU/hr. COP_H if $BTU/h_{cool} \geq 65,000$ BTU/hr. See table above.
If early replacement, HEF_{base} will be the efficiency of the existing unit for the remainder of its useful life (RUL). At the end of its RUL, HEF_{base} becomes code minimum. New Construction and Time of Sale always use code minimum.
- HEF_{ee} = Heating Efficiency Factor of actual VRF system.
HSPF if $BTU/h_{cool} < 65,000$ BTU/hr. COP_H if $BTU/h_{cool} \geq 65,000$ BTU/hr. See table above.
- HU = Heating Units factor. If HEF are in HSPF, $HU = 1000$ (BTU/kBTU). If HEF are in COP, $HU = 3412$ (BTU/kWh).
- $EFLH_{heat}$ = Full load hours for heating equipment.
= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = BTU/h_{cool} / 1000 * (1/EER_{base} - 1/EER_{ee}) * CF.$$

Where:

- EER_{base}

=

EER of baseline unit.

 - If early replacement, EER_{base} will be the efficiency of the existing unit for its Remaining Useful Life (RUL). At the end of its RUL, EER_{base} becomes code minimum. New Construction and Time of Sale always use code minimum.
- EER_{ee}

=

EER of installed VRF system.
- CF_{PJM}

=

PJM Summer Peak Coincidence Factor valued at peak weather.

0.360 for units <135 kBtu/h and 0.567 for units ≥135 kBtu/h.¹¹⁴⁸
- CF_{SSP}

=

Summer System Peak Coincidence Factor

0.588 for units <135 kBtu/h and 0.874 for units ≥135 kBtu/h.¹¹⁴⁹

Annual Fossil Fuel Savings Algorithm

¹¹⁴⁸ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011

¹¹⁴⁹ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, “Report Revision Memo,” KEMA, August 2011.

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta\text{MMBtu} = \text{BTU/h}_{\text{heat}} \times \text{EFLH}_{\text{heat}} / \text{TE} / 1,000,000$$

Where:

- $\text{EFLH}_{\text{heat}}$

=

Full load hours for heating equipment. See table above.
- TE

=

Thermal Efficiency of baseline equipment. If unknown use 80% for units with a heating capacity $\leq 2,500$ kBtu/h and 82% for units with a heating capacity $> 2,500$ kBtu/h.¹¹⁵⁰

Incremental Cost

The incremental costs are assumed to be as follows.

Installation Type	Baseline	Capacity	Incremental Cost (\$/ton) ¹¹⁵¹
Replace on Burnout	Replacing Packaged Unitary Unit w/VAV	All	\$540
	Replacing Single Zone Packaged	All	\$835

¹¹⁵⁰ IECC 2018, Table C403.3.2(5).

¹¹⁵¹ PG&E workpaper PGECOHC142 and SCE workpaper SCE13HC036.1.

Installation Type	Baseline	Capacity	Incremental Cost (\$/ton) ¹¹⁵¹
	AC + Gas Furnace	All	\$860
	Replacing Single Zone Packaged Air-Source Heat Pump		
Early Replacement	Replacing Packaged Unitary Unit	All	\$737 ¹¹⁵²
New Construction	Code-Minimum VRF	All	Attain quote from contractor on cost of installed VRF vs. a code compliant VRF

Measure Life

The measure life is assumed to be 15 years.¹¹⁵³

¹¹⁵² NPV analysis of PG&E workpaper PGECOHVC142 and SCE workpaper SCE13HC036.1. with assumptions of 2.2% inflation and 5% discount rate.

¹¹⁵³ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, <http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf>.

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Operation and Maintenance Impacts
n/a

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Steam Boiler Traps – Repair/Replace

Unique Measure Code(s): CI_HV_TOS_TRAP_0619
Effective Date: June, 2019
End Date: TBD

Measure Description

This measure describes the replacement or repair of a medium to high pressure process boiler’s steam traps where at least one steam trap is not functioning properly and needs to be repaired. Often, traps fail open, meaning that heat escapes constantly during normal operation, thus wasting much available energy. This measure involves fixing or replacing broken traps to ensure proper operation.

Definition of Baseline Condition

To qualify for this measure, customers must have leaking or failed closed steam traps. This measure is intended only to replace traps that are not functioning properly. There is no minimum leak rate.

Definition of Efficient Condition

A boiler with all steam traps functioning properly.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta\text{MMBTU} = (\text{SteamTrapDischargeRate} * \text{HOURS} * h_{fg}) / (\eta_{\text{Boiler}} * 1,000,000)$$

$$\text{SteamTrapDischargeRate} = 24.24^{1154} * \text{Dia}^2 * P_a * 50\%$$

$$P_a = \text{psig} + \text{psia}$$

Where:

<i>SteamTrapDischargeRate</i>	= Hourly rate of steam loss per trap (lb/hr).
<i>HOURS</i>	= Actual operating hours/year = If actual operating hours are unknown, use the Steam Trap Default Table below.
<i>h_{fg}</i>	= Latent heat of vaporization (Btu/lb). See Heat of Vaporization table below.
<i>η_{Boiler}</i>	= Thermal efficiency of boiler. Assume 80.7% ¹¹⁵⁵ if unknown.
<i>Dia</i>	= Internal diameter of steam trap orifice. Use default value from Steam Trap Default table below if unknown.
<i>P_a</i>	= Absolute steam pressure (psi)
<i>psig</i>	= Steam gage pressure (psi). Use default value from Steam Trap Default table below if unknown.
<i>psia</i>	= Atmospheric pressure (psi). Use standard atmospheric value, 14.7, if unknown.

¹¹⁵⁴ 24.24 = Steam loss constant per Napier’s equation (lb/hr-psia-in2)
¹¹⁵⁵ T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993

50% = Deemed value for percent of orifice open.

Heat of Vaporization¹¹⁵⁶

Pressure (psig)	Heat of Vaporization (Btu/lb)
16	944
20	939
30	929
40	920
50	912
60	906
75	895
100	880
125	868
150	857
175	847
200	837
225	828
250	820
275	812
300	805

Steam Trap Default Table

¹¹⁵⁶ The Engineering Toolbox, Properties of Saturated Steam - Imperial Units, https://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html

Steam System	Average Steam Trap Inlet Pressure (psig) ¹¹⁵⁷	Dia (diameter of orifice, in.)	HOURS ¹¹⁵⁸
Medium Pressure (>15 psig, <30 psig)	16	0.1875	8,631
Medium Pressure (≥30 psig, <75 psig)	47	0.2500	8,284
High Pressure (≥75 psig, <125 psig)	101	0.2500	8,100
High Pressure (≥125 psig, <175 psig)	146	0.2500	8,346
High Pressure (≥175 psig, <250 psig)	202	0.2500	7,788
High Pressure (≥250 psig, ≤300 psig)	263	0.2500	8,746
High Pressure (>300 psig)	Custom	Custom	8,746

Annual Water Savings Algorithm

n/a

Incremental Cost

¹¹⁵⁷ Medium and high pressure steam trap inlet pressure based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours.

¹¹⁵⁸ Navigant analysis of Nicor Gas data from GPY1 to GPY3, “TRM Version 4.0 Steam Trap Measure Review”, October 2015

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Steam System	Cost per trap (\$) ¹¹⁵⁹
Industrial Medium Pressure >15 < 30 psig	\$214
Industrial Medium Pressure ≥30 <75 psig	\$265
Industrial High Pressure ≥75 <125 psig	\$328
Industrial High Pressure ≥125 <175 psig	\$383
Industrial High Pressure ≥175 <250 psig	\$440
Industrial High Pressure ≥250 psig	\$497

Measure Life
6 years ¹¹⁶⁰

Operation and Maintenance Impacts
n/a

¹¹⁵⁹ CLEARResult "Steam Traps Revision #1" dated August 2011, adjusted for 8 years of inflation at 2.2%.

¹¹⁶⁰ CA DEER - 2014 Updated EUL Records

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Boiler Reset and Cut-Out Controls

Unique Measure Code(s): CI_HV_TOS_RESET_0619
Effective Date: June, 2019
End Date: TBD

Measure Description

Boiler reset controls improve system efficiency by varying the boiler entering water temperature relative to heating load as a function of the outdoor air temperature. The water can be run cooler during fall and spring than during the coldest parts of the winter. Boiler cut-out controls turn off a boiler and its connected heating system when sensors determine that the outside air has reached a specified temperature. Optionally, a timer to de-energize the heating equipment may also be included.

Most often, these controls are installed together, as controls do exist which can accomplish both functions.

Definition of Baseline Condition

Existing boiler without boiler reset or cut-out controls.

Definition of Efficient Condition

Installation of boiler reset controls and/or boiler cut-out controls. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer’s recommended minimum return temperature. Because boiler reset savings is minimal for non-condensing boilers, this measure is limited to cut-out controls on non-condensing boilers while both boiler reset and cut-out controls are applicable to condensing boilers.

Annual Energy Savings Algorithm

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n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$\Delta\text{MMBTU} = (\text{Savings \%}) * (\text{HOURS}_{\text{heat}} * \text{CAP} * 1/\text{Eff}) / 1,000,000$

Where:

- Savings %

= Estimated percent reduction in heating load due to controls being installed. See Savings Percentage table below.
- HOURS_{heat}

= Full Load Heating Hours.
= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.
- CAP

= Capacity of boiler (BTU/hr).
- Eff

= Actual.
= The efficiency of the boiler; Can be expressed as thermal efficiency (E_t), combustion efficiency (E_c), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.

= If unknown see “Baseline Equipment Efficiency” table in the “Reference Tables” section below¹¹⁶¹.

Savings Percentage	
Boiler Reset	5.0% ¹¹⁶²
Boiler Cut-Out	2.2% ¹¹⁶³
Boiler Reset & Cut-Out	7.1%

Annual Water Savings Algorithm
n/a

Incremental Cost
The cost of this measure is \$812.¹¹⁶⁴

¹¹⁶¹ Baseline efficiencies based on ASHRAE 90.1-2016, Table 6.8.1-6 Gas- and Oil-Fired Boilers- Minimum Efficiency Requirements.

¹¹⁶² GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks, Table 6-4: Commercial Measure Characteristics; Energy Solutions Center. The savings factor of 5% matches between the Residential NY TRM measure and the Residential NEEP measure - therefore, since 5% was also used in the NY TRM for the Commercial measure, it is used here.

¹¹⁶³ Arkansas Technical Reference Manual, Version 7, Volume 2, page 234 and 229. The savings factors for Reset (3.8%) and Cut-Out (1.7%) were used to scale the Cut-Out savings factor proportionally to 2.2%.

¹¹⁶⁴ Nexant. Questar DSM Market Characterization Report. August 9, 2006, adjusted for 2.2% inflation for 13 years

Measure Life
15 years¹¹⁶⁵

Operation and Maintenance Impacts
n/a

Reference Tables

Baseline Equipment Efficiency¹¹⁶⁶

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency after 3/2/2020
Boilers, Gas-fired	<300,000 BTU/h	Hot water	82% AFUE
		Steam	80% AFUE
	≥300,000 BTU/h and ≤2,500,000 BTU/h	Hot water	80% E _t
		Steam – all, except natural draft	79.0% E _t
		Steam – natural draft	79.0% E _t
	>2,500,000 BTU/h	Hot water	82.0% E _c
		Steam – all, except natural draft	79.0% E _t
		Steam – natural draft	79.0% E _t

¹¹⁶⁵ New York State TRM v4.0, April 2016
¹¹⁶⁶ Baseline efficiencies based ASHRAE 90.1-2016, Table 6.8.1-6 Gas- and Oil-Fired Boilers- Minimum Efficiency Requirements.

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Commercial Gas Furnace $\geq 225,000$ BTU/h

Unique Measure Code: CI_HV_TOS_GASFURN_0619

Effective Date: June, 2019

End Date: TBD

Measure Description

This measure applies to the installation of a high efficiency gas furnace with an input capacity greater than or equal to 225,000 BTU/h, in place of a standard efficiency gas furnace. This measure applies to time of sale opportunities in the C&I market used in non-residential or multi-family residential installation.

A commercial warm air furnace means a self-contained oil-fired or gas-fired furnace, $\geq 225,000$ BTU/hr, designed to supply heated air through ducts to spaces that require it and includes combination warm air furnace/electric air conditioning units but does not include unit heaters and duct furnaces.¹¹⁶⁷

Definition of Baseline Condition

The baseline condition is a gas furnace with a Thermal Efficiency (TE) of 80%¹¹⁶⁸.

Definition of Efficient Condition

The efficient condition is a gas furnace with a TE of $\geq 90\%$.

Annual Electric Energy Savings Algorithm

NA

Summer Coincident Peak kW Savings Algorithm

¹¹⁶⁷ [CFR Title 10 → Chapter II → Subchapter D → §431.71](#)

¹¹⁶⁸ [CFR Title 10 → Chapter II → Subchapter D → §431.77](#)

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NA

Annual Fossil Fuel Savings Algorithm

$\Delta\text{MMBTU} = (\text{CAP} * \text{HOURS} * (1/\text{TE}_{\text{Base}} - 1/\text{TE}_{\text{Eff}}) / 1,000,000)$

Where:

- HOURS_{heating}*

= Full Load Heating Hours.
- = If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information*
- CAP*

= Capacity of the high-efficiency equipment [BTU/h].
- = Actual Installed.*
- TE_{base}*

= Thermal Efficiency of the baseline equipment.
- = 0.80*
- TE_{ee}*

= Thermal Efficiency of the efficient equipment.
- = Actual Installed.*
- 1,000,000*

= BTU/MMBTU unit conversion factor.

Example Calculation for MMBtu reduction of a 90%TE 400,000 Btu furnace in a sit-down restaurant in Dover DE:

Annual Gas MMBtu savings
 $\Delta\text{MMBTU} = 400,000 * 1,131 * (1/.80 - 1/.90) / 1,000,000$
 $= 62.8 \text{ MMBtu}$

Annual Water Savings Algorithm

n/a

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Incremental Cost

There is not currently enough information to inform incremental cost. Implementers should cost out comparable, baseline equipment as a custom measure.

Measure Life

The measure life is assumed to be 23 years¹¹⁶⁹.

Operation and Maintenance Impacts

n/a

¹¹⁶⁹ [EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018 \(prepared by Navigant Consulting, Inc.\)](#)

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Infrared Heaters

Unique Measure Code(s): CI_HV_TOS_IRHEAT_0619
Effective Date: June 2019
End Date: TBD

Measure Description

This measure refers to the installation of gas-fired infrared heaters in new buildings or installation with the purpose of replacing existing gas-fired furnaces or unit heaters.

Definition of Baseline Condition

The baseline for this measure is a standard natural gas-fired heater.

Definition of Efficient Condition

The efficient condition is a gas-fired low or medium intensity infrared heater.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta\text{MMBTU} = (1 - \text{LRF}) * \text{CAP} * \text{HOURS}_{\text{heat}} / 1,000,000$$

$$LRF = HDD45 / (55^{\circ}F - T_{design}) / (HDD55 / (65^{\circ}F - T_{design}))^{1170}$$

- Where:
- LRF = Load Reduction Factor
 - CAP = The input capacity of the infrared heater (BTU/hr).
= Actual installed.
 - HOURS_{heat} = Full Load Heating Hours.
= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.
 - HDD45 = Heating degree-days of the climate zone, base of 45 degrees
 - HDD55 = Heating degree-days of the climate zone, base of 55 degrees
 - T_{design} = Equipment design temperature relative to local climate

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental capital cost for this measure is \$2,042.¹¹⁷¹

Measure Life
12 years¹¹⁷²

¹¹⁷⁰ Minnesota TRM Version 2.2, May 2018. Page 383-386, “C/I HVAC - Infrared Heater”.
¹¹⁷¹ ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011, adjusted for 8 years of inflation at 2.2%.
¹¹⁷² Ibid.

Operation and Maintenance Impacts

n/a

Reference Tables

HDD, T_{design} and LRF values for selected cities¹¹⁷³

	HDD45	HDD55	T _{design}	LRF
Wilmington, DE	840	1697	11 F	60.75%
Baltimore, MD	721	1499	15 F	60.12%
Washington, DC	560	1325	18 F	53.69%

¹¹⁷³ Values based on TMY3 data. T_{design} placed at 99% percent lowest temperature.

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Commercial Infrared HeatersDuct Sealing

Unique Measure Code(s): CI_HV_HV_TOS_IRHEAT_0619DUCTSEAL

Effective Date: January 2025June 2019

End Date: TBD

Measure Description

This measure was developed to reduce the heating and cooling losses from ducts running through un-conditioned spaces, including, but not limited to: unheated/uncooled attics, basements or crawlspaces; or the outdoors. To the extent that the duct runs through a conditioned space, such as occupied rooms, between conditioned building floors, or semi-heated or semi-cooled spaces, this measure is not applicable as it is assumed that all heating or cooling losses from the duct perform beneficial heating or cooling to the conditioned space. This assumption ignores the potential overheating and overcooling of the conditioned space, which energy waste is hereby deemed to be negligible.measure refers to the installation of gas-fired infrared heaters in new buildings or installation with the purpose of replacing existing gas-fired furnaces or unit heaters.

Definition of Baseline Condition

The Baseline equipment is an uninsulated and/or un-sealed duct located within an un-conditioned space. If a duct has previously been insulated but a significant portion of the insulation has deteriorated or fallen off, the program shall verify the duct insulation condition and determine whether the duct can be considered “un-insulated” for purposes of applying for an incentive.baseline for this measure is a standard natural gas-fired heater.

Definition of Efficient Condition

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The efficient case is installing duct wrap or other insulation to a length of HVAC ductwork. If applied to ductwork that currently, or in the future may transmit cooling air, the insulation must be wrapped with an impermeable vapor barrier.

The efficient duct air sealing case is installing elastomeric sealant externally to cracks and holes in ductwork that completely and permanently seals the ductwork from air leakage. The elastomeric material must remain flexible and adhere to the ductwork during the measure lifetime and to withstand significant swings in ductwork temperature without losing its sealing capability. efficient condition is a gas-fired low or medium intensity infrared heater.

Annual Energy Savings Algorithm

Where available, savings from duct insulation measures should be determined through a custom analysis. When that is not feasible for the program, the following engineering algorithms can be used.

$$\Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{heatingElectric} + \Delta kWh_{heatingGas}$$

Where:

$$\Delta kWh_{cooling} = \frac{EFLH_{Cool} * (A_{Duct} * (1/R_{DuctExist} - 1/R_{DuctEfficient}) + 1.08 * CFM_{Saved})}{1000 * \eta_{Cool}}$$

Where:

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Average Crack Width (Inches)	CFM Air Leakage per Foot of Crack @ 0.3 w.c. duct
0.00	0 CFM
0.05	7 CFM
0.10	13 CFM
0.15 (Default if Unknown)	20 CFM
0.20	26 CFM

1176 [ASHRAE Fundamentals \(2017\), Page 16.28, Fig. 14: "For other dP, Multiply Leakage Rate by \(dP/0.3\)^0.55"](#) .

[illegible]

0.25	33 CFM
0.30	39 CFM
0.35	46 CFM
0.40	52 CFM
0.45	59 CFM
0.50	65 CFM
Unknown	20 CFM

$EFLH_{Cool, R-Duct_{Efficient}}$ = Equivalent Full Load Hours for cooling in Existing Buildings
Average R-value of proposed duct assembly after installation of additional insulation

= Actual
 $Avg_{Clg} OATR_{Duct_{Efficient}}$ = Deemed average ambient air temperature over the cooling season in the building space through which the HVAC duct runs, based on climate zone
Average R-value value of existing duct assembly, including any existing insulation
= if duct is uninsulated, the average R-value deemed to be 0.8 hr-sf-F/BTU

$Avg_{Duct} Clg_{SAT} R_{Duct_{Efficient}}$ = Average R-value of proposed duct assembly after installation of additional insulation
60degF
= Actual

$\eta_{Cool, R-Duct_{Efficient}}$ = Efficiency of cooling system. Actual, if known. Alternatively, use federal minimum standards as default if unknown.
Average R-value value of existing duct assembly, including any existing insulation

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= if duct is uninsulated, the average R-value deemed to be 0.8 hr-sf-F/BTU

%Cool = Percent of building where duct insulation is to be installed that is cooled Equivalent Full Load Hours for cooling in Existing Buildings
= Actual %, if known, or, If actual % unknown, use following deemed values;

Is Space Being Insulated Cooled?	Deemed %Cool, if actual % is unknown
<u>Yes</u>	<u>100%</u>
<u>No</u>	<u>0%</u>

ΔkWh heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to wall and/or foundation insulation if building is cooled, reduction in annual cooling requirement due to duct insulation

$$= [(1 / R_{DuctExist} - 1 / R_{DuctEfficient}) * A_{Duct} + 1.08 * CFM_{Saved}] * EFLH_{Heat} * (Avg_{Htg} SAT - Avg_{Duct} Htg_{OAT}) / \eta_{Heat} / 3412 * \%ElectricHeat \{ (1 / R_{DuctExist} - 1 / R_{DuctEfficient}) * A_{Duct} + 1.08 * CFM_{Saved} \} * EFLH_{Cool} * (Avg_{Clg} OAT - Avg_{Duct} Clg_{SAT}) / 1000 / \eta_{Cool} * \%Cool$$

Where:

R_{DuctEfficient} = Average R-value of proposed duct assembly after installation of additional insulation

EFLH_{Heat} = Equivalent Full Load Hours for heating in Existing Buildings

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Avg. Htg. OAT = Deemed average ambient air temperature over the heating season in the building space through which the HVAC duct runs, based on climate zone

Avg. Duct Htg. SAT = 85degF

η_{Heat} = Efficiency of heating system, as deemed from table below

<u>System Type</u>	<u>Cooling Capacity of Equipment</u>	<u>Age of Equipment</u>	<u>HSPF Estimate</u>	<u>η (Effective COP Estimate) (HSPF/3.413)</u>
<u>Heat Pump</u> ¹⁰⁴²	<u>All</u>	<u>Before 2009</u>	<u>6.8</u>	<u>2.0</u>
	<u>< 65,000 Btu/h</u>	<u>2009 - 2017</u>	<u>7.7</u>	<u>2.3</u>
		<u>2017 on</u>	<u>8.2</u>	<u>2.40</u>
	<u>≥ 65,000 Btu/h and < 135,000 Btu/h</u>	<u>2010 on</u>	<u>11.3</u>	<u>3.3</u>
	<u>≥ 135,000 Btu/h and < 240,000 Btu/h</u>	<u>2010 on</u>	<u>10.9</u>	<u>3.2</u>
	<u>≥ 240,000 Btu/h and < 760,000 Btu/h</u>	<u>2010 on</u>	<u>10.9</u>	<u>3.2</u>
<u>Resistance</u>	<u>N/A</u>	<u>N/A</u>	<u>N/A</u>	<u>1</u>
<u>Natural Gas Furnace or Boiler</u>	<u>N/A</u>	<u>N/A</u>	<u>N/A</u>	<u>0.8 E_r</u>

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<u>System Type</u>	<u>Cooling Capacity of Equipment</u>	<u>Age of Equipment</u>	<u>HSPF Estimate</u>	<u>η (Effective COP Estimate) (HSPF/3.413)</u>
	<u>All</u>	<u>Before 2009</u>	<u>6.8</u>	<u>2.0</u>
	<u>< 65,000 Btu/h</u>	<u>2009 - 2017</u>	<u>7.7</u>	<u>2.3</u>
		<u>2017 on</u>	<u>8.2</u>	<u>2.40</u>

Heat Pump ¹⁰⁴²	$\geq 65,000 \text{ Btu/h and } < 135,000 \text{ Btu/h}$	2010 on	11.3	3.2
	$\geq 135,000 \text{ Btu/h and } < 240,000 \text{ Btu/h}$	2010 on	10.9	3.2
	$\geq 240,000 \text{ Btu/h and } < 760,000 \text{ Btu/h}$	2010 on	10.9	3.2
Resistance	N/A	N/A	N/A	1
Natural Gas Furnace or Boiler	N/A	N/A	N/A	0.8

η_{Cool} = Efficiency of cooling system. Actual, if known. Alternatively, use federal minimum standards as default if unknown.

$\%ElectricHeat$ = Percent of building where duct insulation is to be installed that is electrically heated
= Actual %, if known, or, If actual % unknown, use following deemed values:

Is Space Being Insulated Electrically Heated?	Deemed %ElectricHeat, if actual % is unknown
Yes	100%
No	0%

$\%Cool$ = Percent of building where duct insulation is to be installed that is cooled
= Actual %, if known, or, If actual % unknown, use following deemed values:

$\Delta kWh_{heatingGas}$ = If gas furnace or boiler heat, kWh savings for reduction in combustion fan run time
= $\Delta Therms * Fe * 29.3$

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F_e = Furnace or boiler combustion fan energy consumption as a percentage of annual fuel consumption
= 7.7%

29.3 = conversion of therms to kWh (= 100000 / 3412)

Other variables as defined above

Summer Coincident Peak kW Savings Algorithm

ΔkW = $\Delta kWh_{cooling} / EFLH_{Cooling} * CF$

Where:

$\Delta kWh_{cooling}$ = Annual kWh saving in cooling energy use, as determined above

$EFLH_{cooling}$ = Equivalent Full Load Hours for cooling in Existing Buildings

CF_{sdp} = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

n/a

Annual Fossil Fuel Savings Algorithm

$\Delta MBTU_{Therms}$ = $[(1 / R_{DuctExist} - 1 / R_{DuctEfficient}) * A_{Duct} + 1.08 * CFM_{Saved}] * EFLH_{Heat} * (Avg_{Htg\_SAT} - Avg_{Duct\_Htg\_OAT}) / \eta_{Heat} / 100,000 * \%GasHeat = (1 - LRF) * CAP * HOURS_{heating} / 1,000,000$

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$$LRF = \frac{HDD45 / (55^{\circ}F - T_{design})}{(HDD55 / (65^{\circ}F - T_{design}))^{1.177}}$$

Where:

%GasHeat = Percent of space being retrofitted with insulation that is heated using gas

= Actual %, if known, or, If actual % unknown, use following deemed values:

Is Space Being Insulated Heated with Gas?	Deemed %GasHeat, if actual % is unknown
Yes	100%
No	0%

LRF = Load Reduction Factor

CAP = The input capacity of the infrared heater (BTU/hr).

Other variables as defined above:

= Actual installed:

HOURS_{sheet} = Full Load Heating Hours.

= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.

HDD45 = Heating degree-days of the climate zone, base of 45 degrees

HDD55 = Heating degree-days of the climate zone, base of 55 degrees

T_{design} = Equipment design temperature relative to local climate

¹¹⁷⁷ Minnesota TRM Version 2.2, May 2018. Page 383-386, “C/I HVAC – Infrared Heater”.

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Annual Water Savings Algorithm

n/a

Incremental Cost

The actual installation cost should be used if known. If unknown, the measure cost for duct insulation, including material and installation, is assumed to be \$8.00 per square foot and for duct crack sealing, including materials and installation, is assumed to be \$15.00 per linear foot. ~~incremental capital cost for this measure is \$2,042.~~¹¹⁷⁸

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Measure Life

The measure life is assumed to be 20 years ~~12 years~~¹¹⁷⁹

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Operation and Maintenance Impacts

n/a

¹¹⁷⁸ ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011, adjusted for 8 years of inflation at 2.2%.

¹¹⁷⁹ Ibid.

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Small Business Infrared HeatersFurnace Tune-Ups

Unique Measure Code(s): CI_HV_TOS_IRHEAT_0619HV_FURNACE_TUNE
Effective Date: ~~June 2019~~January 2025
End Date: TBD

Measure Description

This measure is for a fossil fuel Small Business furnace or Gas-Fired Rooftop Unit that provides space heating. The tune-up will improve furnace or gas-fired rooftop unit performance by inspecting, cleaning, and adjusting the furnace or rooftop unit and appurtenances for correct and efficient operation. Additional savings may be realized through a complete system tune-up. ~~This measure refers to the installation of gas-fired infrared heaters in new buildings or installation with the purpose of replacing existing gas-fired furnaces or unit heaters.~~

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Definition of Baseline Condition

The baseline equipment is a furnace or a gas-fired rooftop unit assumed not to have had a tune-up in the past 3 years. ~~The baseline for this measure is a standard natural gas-fired heater.~~

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Definition of Efficient Condition

To qualify for this measure an approved technician must complete the tune-up requirements listed below. ~~The efficient condition is a gas-fired low or medium intensity infrared heater.~~

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Where applicable lubricate motor and inspect and replace fan belt, if required
- Inspect for gas leaks

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- [Clean burner per manufacturer’s recommendations and adjust as needed](#)
- [Check ignition system and safety systems and clean and adjust as needed](#)
- [Check and clean heat exchanger per manufacturer’s recommendations](#)
- [Inspect exhaust/flue for proper attachment and operation](#)
- [Inspect control box, wiring and controls for proper connections and performance](#)
- [Check air filter and clean or replace per manufacturer’s recommendations](#)
- [Inspect duct work connected to furnace for leaks or blockages](#)
- [Measure temperature rise and adjust flow as needed](#)
- [Check for correct line and load volts/amps](#)
- [Check thermostat operation is per manufacturer’s recommendations \(if adjustments made, refer to ‘Small Commercial Programmable Smart Thermostat Adjustment’-measure for savings estimate\)](#)
- [Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits](#)

Annual Energy Savings Algorithm

$$\Delta MM\text{BTU/kWh} = \Delta\text{Therms} * Fe * 29.3 (1 - LRF) * CAP * \text{HOURS}_{\text{heat}} / 1,000,000$$

Where:

ΔTherms = [As Calculated Below](#)

Fe = [Furnace or rooftop fan energy consumption as a percentage of annual fuel consumption. If unknown, use 7.7%¹¹⁸⁰](#)

¹¹⁸⁰ Per IL 2024 TRM - Fe is estimated using TRM models for the three most popular building types for programmable thermostats: low-rise office (10.2%), sit-down restaurant (8.6%), and retail - strip mall (4.4%). 7.7% reflects the average Fe of the three building types.

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$$\frac{LRF = HDD45 / (55^{\circ}F - T_{design}) / (HDD55 / (65^{\circ}F - T_{design}))^{1181}}{n/a}$$

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Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta Therms = \frac{(Capacity * EFLH * (((Eff_{before} + E_{\#}) / Eff_{before}) - 1)) / 100,000 \Delta MM BTU}{1,000,000} = (1 - LRF) * CAP * HOURS_{heat} /$$

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$$LRF = HDD45 / (55^{\circ}F - T_{design}) / (HDD55 / (65^{\circ}F - T_{design}))^{1182}$$

Where:

$Capacity_{LRF}$ = Load Reduction Factor Furnace Gas Input Size (BTU/hr)
 $CAPEFLH$ = The input capacity of the infrared heater
(BTU/hr)-Equivalent Full Load Hours for Heating in Existing Buildings
= Actual installed.

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$HOURS_{heat} Eff_{before}$ = Efficiency of the furnace before the tune-up Full
Load Heating Hours.

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up

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¹¹⁸¹ Minnesota TRM Version 2.2, May 2018, Page 383-386, "C/I HVAC - Infrared Heater"

¹¹⁸² Minnesota TRM Version 2.2, May 2018, Page 383-386, "C/I HVAC - Infrared Heater"

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= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.

$HDD_{45}E_{ieff}$ = Heating degree-days of the climate zone, base of 45 degrees

Efficiency improvement of the furnace tune-up measure

HDD_{55} = Heating degree days of the climate zone, base of 55 degrees

T_{design} = Equipment design temperature relative to local climate

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Annual Water Savings Algorithm

n/a

Incremental Cost

n/a

The incremental capital cost for this measure is \$2,042.¹¹⁸³

Measure Life

312 years¹¹⁸⁴

Operation and Maintenance Impacts

n/a

¹¹⁸³ ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011, adjusted for 8 years of inflation at 2.2%.

¹¹⁸⁴ Assumed consistent with other tune-up measures. For more detail, see: 4.4.1 Air Conditioner Tune-Up (3 years is given for “Clean Condenser Coils - Commercial” and “Clean Evaporator Coils”, DEER2014 EUL Table.) and 4.4.2 Space Heating Boiler Tune-Up (Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up.)~~bid.~~

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Space Heating Boiler Tune-Ups

Unique Measure Code(s): CI_HV_SP_BOILER_TUNE
Effective Date: January 2025
End Date: TBD

Measure Description

This measure is for a non-residential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer. ~~This measure refers to the installation of gas-fired infrared heaters in new buildings or installation with the purpose of replacing existing gas-fired furnaces or unit heaters.~~

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Definition of Baseline Condition

~~The~~The baseline condition of this measure is a boiler that has not had a tune-up within the past 3 years. ~~baseline for this measure is a standard natural gas-fired heater.~~

Definition of Efficient Condition

To qualify for this measure the facility must, as applicable, complete the tune-up requirements listed below¹¹⁸⁵. ~~The efficient condition is a gas-fired low or medium intensity infrared heater.~~

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- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures

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¹¹⁸⁵ Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.*
- Inspect gaskets on front and rear doors and replace as necessary.*
- Seal and close front and rear doors properly.*
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.*
- Clean plugs in control piping.*
- Remove all hand hole and manhole plates. Flush boiler with water to remove loose scale and sediment.*
- Replace all hand hole and manhole plates with new gaskets.*
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.*
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.*
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and manhole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel

Note: Tune-up activities marked with an asterisk (*) are eligible to be performed by internal maintenance staff at periods of boiler shutdown.

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Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\frac{\Delta MM\text{BTU}_{\text{Therms}}}{\text{LRF}} = \frac{(\text{Capacity} * \text{EFLH} * (((\text{Eff}_{\text{before}} + E_f) / \text{Eff}_{\text{before}}) - 1)) / 100,000}{\text{CAP} * \text{HOURS}_{\text{heat}} / 1,000,000}$$

Where:

- Capacity = Furnace Gas Input Size (BTU/hr)
- EFLH = Equivalent Full Load Hours for Heating in Existing Buildings
= Actual installed.
- Eff_{before} = Efficiency of the boiler before the tune-up.
= If unknown, use 81.5%¹¹⁸⁶

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up

¹¹⁸⁶ Guidehouse evaluation results from tune-up efficiency improvement research for Peoples Gas and North Shore Gas through their C&I and Public Sector Prescriptive Rebate Program, their Small Business Program, and their Multi-Family Programs. The evaluation included project and population data from program year's 2018 and 2019.

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$$E_i = \frac{\text{Efficiency improvement of the furnace tune-up measure}}{\frac{LRF = HDD45 / (55^{\circ}\text{F} - T_{\text{design}}) / (HDD55 / (65^{\circ}\text{F} - T_{\text{design}}))^{1187}}{= \text{If unknown, use 2.3\%}^{1188}}$$

Where:

LRF = Load Reduction Factor

CAP = The input capacity of the infrared heater (BTU/hr).

= Actual installed.

HOURS_{heat} = Full Load Heating Hours.

= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F.

Otherwise, use site specific full load heating hours information.

HDD45 = Heating degree-days of the climate zone, base of 45 degrees

HDD55 = Heating degree-days of the climate zone, base of 55 degrees

T_{design} = Equipment design temperature relative to local climate

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Annual Water Savings Algorithm

n/a

Incremental Cost

¹¹⁸⁷ Minnesota TRM Version 2.2, May 2018. Page 383-386, “C/I HVAC—Infrared Heater”

¹¹⁸⁸ Guidehouse evaluation results from tune-up efficiency improvement research for Peoples Gas and North Shore Gas through their C&I and Public Sector Prescriptive Rebate Program, their Small Business Program, and their Multi-Family Programs. The evaluation included project and population data from program year’s 2018 and 2019.

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The incremental capital cost for this measure is \$0.83/MMBtuh per tune-up¹¹⁸⁹ ~~2,042~~¹¹⁹⁰

Measure Life
312 years¹¹⁹¹

Operation and Maintenance Impacts
n/a

¹¹⁸⁹ Work Paper - Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012.

¹¹⁹⁰ ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011, adjusted for 8 years of inflation at 2.2%.

¹¹⁹¹ Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up Ibid.

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DHW Boiler Tune-Up

Unique Measure Code(s): CI_HV_DHW_BOILER_TUNE
Effective Date: January 2025
End Date: TBD

Measure Description

Domestic hot water (DHW) boilers provide hot water for bathrooms, kitchens, tubs and other appliances. Several commercial and industrial facilities such as multi-family buildings, lodging and restaurants have a separate hot water boiler serving DHW loads. Unlike space heating boilers, DHW boilers operate year round, which means they have a greater need to be properly maintained and tuned up.

This measure calculates savings for tuning up a DHW boiler to improve its efficiency and reduce its consumption. A boiler tune-up involves cleaning/inspecting burners, burner nozzles and combustion chambers, adjusting air flow and burner gas input to reduce stack temperatures, and checking venting and safety controls. A pre- and post- tune up combustion efficiency ticket (from combustion analyzer) can be used to confirm the improvement in boiler efficiency.

Boilers that serve only a DHW load are eligible for this measure.

Definition of Baseline Condition

The baseline condition of this measure is a boiler that has not had a tune-up within the past 3 years.

Definition of Efficient Condition

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To qualify for this measure the facility must, as applicable, complete the tune-up requirements listed below¹¹⁹²

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and manhole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and manhole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.

¹¹⁹² Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

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- [Perform all flame safeguard and safety trip checks.](#)
- [Check all hand hole plates and manhole plates for leaks at normal operating temperatures and pressures.](#)
- [Troubleshoot any boiler system problems as requested by on-site personnel](#)

[Annual Energy Savings Algorithm](#)
n/a

[Summer Coincident Peak kW Savings Algorithm](#)
n/a

[Annual Fossil Fuel Savings Algorithm](#)

$$\Delta Therms = \frac{(T_{out} - T_{in}) * HotWaterUse_{Gallon} * \rho_{water} * 1 * (1/Eff_{before} - 1/Eff_{after})}{100,000}$$

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[Where:](#)

$$T_{OUT} = \text{Hot water storage tank temperature}$$

$$= 125^{\circ}F$$

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$$T_{IN} = \text{Incoming water temperature}$$

$$= 54^{\circ}F$$

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$$\frac{HotWaterUse_{Gallon}}{(gallons)Efficiency\ of\ the\ boiler\ before\ the\ tune\ up.} = \text{Estimated annual hot water consumption}$$

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= If unknown, use 81.5%⁴¹⁹³ estimate using one of the following methods:

1. Consumption per usable storage tank capacity
= Capacity * Consumption/Cap

Where:
Capacity = Usable capacity of tank in gallons

Consumption/Cap = Estimate of consumption per gallon of
usable tank capacity, based on building
type¹¹⁹⁴

Building Type	Consumption/Cap
Convenience	528
Education	568
Grocery	528
Health	788
Large Office	511
Large Retail	528
Lodging	715
Other Commercial	341
Restaurant	622
Small Office	511
Small Retail	528

⁴¹⁹³ Guidehouse evaluation results from tune-up efficiency improvement research for Peoples Gas and North Shore Gas through their C&I and Public Sector Prescriptive Rebate Program, their Small Business Program, and their Multi-Family Programs. The evaluation included project and population data from program year's 2018 and 2019.

¹¹⁹⁴ According to CBECS 2012 "Lodging" buildings include Dormitories, Hotels, Motel or Inns and other Lodging and "Nursing" buildings include Assisted Living and Nursing Homes.

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Warehouse	341
Nursing	672
Multi-Family	894

2. [Consumption per usable storage tank capacity](#)
[= Capacity * Consumption/Cap](#)

[Where:](#)
[Capacity](#) = [Usable capacity of tank in gallons](#)

[Consumption/Cap](#) = [Estimate of DHW consumption per 1,000 sq.ft based on building type](#) [Note:](#)
[Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune up](#)

Building Type	Consumption /1,000 sq.ft
Convenience	4,594
Education	7,285
Grocery	697
Health	24,540
Large Office	1,818
Large Retail	1,354
Lodging	29,548
Other Commercial	3,941
Restaurant	44,439
Small Office	1,540
Small Retail	6,111

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Warehouse	1,239
Nursing	30,503
Multi-Family	15,434

V_{water} = Specific weight capacity of water (lb/gal)
= 8.33 lbs/gal

Eff_{before} = Efficiency of the boiler before tune-up

Eff_{after} = Efficiency of the boiler after tune-up

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the year and take readings at a consistent firing rate for pre and post tune-up

E_s = Efficiency improvement of the furnace tune-up measure
= If unknown, use 2.3%¹¹⁹⁵

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost for this measure is \$0.83/MMBtuh per tune-up¹¹⁹⁶

Measure Life

¹¹⁹⁵ Guidehouse evaluation results from tune-up efficiency improvement research for Peoples Gas and North Shore Gas through their C&I and Public Sector Prescriptive Rebate Program, their Small Business Program, and their Multi-Family Programs. The evaluation included project and population data from program year's 2018 and 2019.

¹¹⁹⁶ Work Paper - Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012

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3 years¹¹⁹⁷

Operation and Maintenance Impacts

n/a

DHW Tune-Ups

Unique Measure Code(s): CI_HV_FURNACE_TUNE

Effective Date: January 2025

End Date: TBD

Measure Description

———— This measure refers to the installation of gas-fired infrared heaters in new buildings or installation with the purpose of replacing existing gas-fired furnaces or unit heaters.

Definition of Baseline Condition

———— The baseline for this measure is a standard natural gas-fired heater.

Definition of Efficient Condition

The efficient condition is a gas-fired low or medium intensity infrared heater.

Annual Energy Savings Algorithm

———— n/a

Summer Coincident Peak kW Savings Algorithm

———— n/a

¹¹⁹⁷ Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

Annual Fossil Fuel Savings Algorithm

$$\text{AMMBTU} = (1 - \text{LRF}) * \text{CAP} * \text{HOURS}_{\text{heat}} / 1,000,000$$

$$\text{LRF} = \text{HDD45} / (55^{\circ}\text{F} - \text{T}_{\text{design}}) / (\text{HDD55} / (65^{\circ}\text{F} - \text{T}_{\text{design}}))^{1.198}$$

- Where:
- LRF = Load Reduction Factor
 - CAP = The input capacity of the infrared heater (BTU/hr).
 - = Actual installed.
 - HOURS_{heat} = Full Load Heating Hours.
 - = If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information.
 - HDD45 = Heating degree days of the climate zone, base of 45 degrees
 - HDD55 = Heating degree days of the climate zone, base of 55 degrees
 - T_{design} = Equipment design temperature relative to local climate

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost for this measure is \$2,042.¹¹⁹⁹

¹¹⁹⁸ Minnesota TRM Version 2.2, May 2018. Page 383-386, “C/I HVAC – Infrared Heater”.

¹¹⁹⁹ ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014, Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011, adjusted for 8 years of inflation at 2.2%.

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Measure Life
12 years¹²⁰⁰

Operation and Maintenance Impacts
n/a

¹²⁰⁰ ibid.

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Refrigeration End Use

ENERGY STAR Commercial Freezers

Unique Measure Code(s): CI_RF_TOS_FREEZER_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency packaged commercial freezer intended for food product storage. This measure may involve the removal of an existing inefficient freezer from service, prior to failure.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a standard-efficiency commercial freezer meeting, but not exceeding, federal energy efficiency standards.

Early Replacement: The baseline condition for the Early Replacement measure is the existing commercial freezer for the remaining useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard.

Definition of Efficient Condition

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The efficient condition is a high-efficiency packaged commercial freezer meeting ENERGY STAR Version 4.0 requirements¹²⁰¹.

Annual Energy Savings Algorithm

Time of Sale or New Construction:

$$\Delta kWh = (kWh_{BASEdaily\max} - kWh_{EEdaily\max}) * 365.$$

Early Replacement:

ΔkWh for remaining life of existing unit:

$$= (kWh_{EXISTdaily\max} - kWh_{EEdaily\max}) * 365$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing equipment):

$$= (kWh_{BASEdaily\max} - kWh_{EEdaily\max}) * 365$$

Where:

$kWh_{BASEdaily\max}$ ¹²⁰² = See “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section below.

¹²⁰¹ ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

¹²⁰² Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

$kWh_{EXISTdaily\max}$ = See "Existing Equipment Efficiency" table in the "Reference Tables" section below

Time of Sale:

Early Replacement:

Where:

CF = Summer Peak Coincidence Factor for measure.

¹²⁰⁴ Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

= 0.77.¹²⁰⁵

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost¹²⁰⁶
The incremental cost for time of sale measure is assumed to be \$0.¹²⁰⁷ For early replacement the incremental costs are listed in the “Early Replacement Remaining Useful Life and Incremental Cost” table in the Reference Tables section below.

Measure Life
The measure life is assumed to be 12 years.¹²⁰⁸

Operation and Maintenance Impacts
n/a

Reference Tables

¹²⁰⁵ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.
¹²⁰⁶ Unit Energy Savings (UES) Measures and Supporting Documentation, ComFreezer_v3_0.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum
¹²⁰⁷ Energy Star Calculator accessed April 25, 2017, which cites Energy Star research, 2014.
¹²⁰⁸ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

Time of Sale Baseline Equipment Efficiency

Product Class	Freezer Energy ($kWh_{BASEdaily\max}$)
Vertical Closed	
<i>Solid</i>	$VCS.SC.L$
All volumes	$0.22V+1.38$
<i>Transparent</i>	$VCT.SC.L$
All volumes	$0.29V+2.95$
Horizontal Closed	
<i>Solid</i>	$HCS.SC.L$
All volumes	$0.06V+1.12$
<i>Transparent</i>	$HCT.SC.L$
All volumes	$0.08V+1.23$

Where V = unit volume in cubic feet

* DOE Equipment Class designations relevant to ENERGY STAR eligible product scope.
(1) Equipment family code (HCS= horizontal closed solid, HCT=horizontal closed transparent, VCS= vertical closed solid, VCT=vertical closed transparent).)
(2) Operating mode (SC=self-contained).)
(3) Rating Temperature (M=medium temperature (38 °F), L=low temperature (0 °F)).)

Time of Sale Energy Star Equipment Efficiency

Product Class	Freezer Energy ($kWh_{EEdaily\max}$)
Vertical Closed	
<i>Solid</i>	$VCS.SC.L$
$0 < V < 15$	$0.21V+0.9$
$15 \leq V < 30$	$0.12V+2.248$

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Product Class	Freezer Energy ($kWh_{EEdaily\max}$)
$30 \leq V < 50$	0.285V-2.703
$50 \leq V$	0.142V+4.445
Transparent	VCT.SC.L
$0 < V < 15$	0.232V+2.36
$15 \leq V < 30$	
$30 \leq V < 50$	
$50 \leq V$	
Horizontal Closed	
Solid or Transparent	HCT.SC.L, HCS.SC.L
All volumes	0.057V+0.55

Where V = unit volume in cubic feet

Existing Equipment Efficiency

Product Class	Freezer Energy when existing unit was manufactured before 03/26/2017 ¹²⁰⁹ ($kWh_{EXISTdaily\max}$)	Freezer Energy when existing unit was manufactured after 03/27/2017 ($kWh_{EXISTdaily\max}$)
Vertical Closed		
Solid	$VCS.SC.L$	$VCS.SC.L$
All volumes	$0.40V + 1.38$	$0.22V + 1.38$
Transparent	$VCT.SC.L$	$VCT.SC.L$
All volumes	$0.75V + 4.10$	$0.29V + 2.95$
Horizontal Closed		

¹²⁰⁹ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2010).

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<i>Solid</i>	<i>HCS.SC.L</i>	<i>HCS.SC.L</i>
All volumes	$0.40V+1.38$	$0.06V+1.12$
<i>Transparent</i>	<i>HCT.SC.L</i>	<i>HCT.SC.L</i>
All volumes	$0.75V+4.10$	$0.08V+1.23$

Where V = Unit volume in cubic feet

Early Replacement Remaining Useful Life and Incremental Cost¹²¹⁰

Age of Existing Unit Being Replaced	Remaining Useful Life (RUL) ¹²¹¹	Incremental Cost of Measure $0 \leq V < 25$	Incremental Cost of Measure $25 \leq V$
0	11	\$ 616	\$ 1,385
1	10	\$ 571	\$ 1,284
2	9	\$ 525	\$ 1,180
3	8	\$ 478	\$ 1,074
4	7	\$ 429	\$ 964
5	7	\$ 429	\$ 964
6	6	\$ 379	\$ 852
7	5	\$ 328	\$ 736
8	5	\$ 328	\$ 736
9	4	\$ 275	\$ 617
10	4	\$ 275	\$ 617
11	4	\$ 275	\$ 617

¹²¹⁰ The early replacement cost factors in the time value of money with a net present value analysis, comparing a purchase today with a purchase at the end of remaining useful life. Net present value analysis using an inflation rate of 2.2% and a discount rate of 5%.

¹²¹¹ Navigant analysis based on Weibull curve for refrigeration remaining useful life <https://aceee.org/files/proceedings/2010/data/papers/1977.pdf>

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12	4	\$ 275	\$ 617
13	3	\$ 220	\$ 495
14	3	\$ 220	\$ 495
15	3	\$ 220	\$ 495
16	3	\$ 220	\$ 495
17	3	\$ 220	\$ 495
18	2	\$ 165	\$ 370
19	2	\$ 165	\$ 370
20	2	\$ 165	\$ 370
21	2	\$ 165	\$ 370
22	2	\$ 165	\$ 370
23	2	\$ 165	\$ 370
24	2	\$ 165	\$ 370
25	2	\$ 165	\$ 370
26	2	\$ 165	\$ 370
27	2	\$ 165	\$ 370
28	2	\$ 165	\$ 370
29	2	\$ 165	\$ 370

Where V = unit volume in cubic feet

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ENERGY STAR Commercial Refrigerator

Unique Measure Code(s): CI_RF_TOS_REFRIG_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency packaged commercial refrigerator intended for food product storage. This measure may involve the removal of an existing inefficient refrigerator from service, prior to failure.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a standard-efficiency commercial refrigerator meeting, but not exceeding, federal energy efficiency standards.

Early Replacement: The baseline condition for the Early Replacement measure is the existing commercial refrigerator for the remaining useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard.

Definition of Efficient Condition

The efficient condition is a high-efficiency packaged commercial refrigerator meeting ENERGY STAR Version 4.0 requirements.¹²¹²

¹²¹² ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

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Annual Energy Savings Algorithm

Time of Sale or New Construction:

$$\Delta kWh = (kWh_{BASEdaily\max} - kWh_{EEdaily\max}) * 365.$$

Early Replacement:

ΔkWh for remaining life of existing unit:

$$= (kWh_{EXISTdaily\max} - kWh_{EEdaily\max}) * 365$$

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing equipment):

$$= (kWh_{BASEdaily\max} - kWh_{EEdaily\max}) * 365$$

Where:

$kWh_{BASEdaily\max}^{1213}$ = See “Time of Sale Baseline Equipment Efficiency” table in the “Reference Tables” section below.

$kWh_{EEdaily\max}^{1214}$ = See “Time of Sale Energy Star Equipment Efficiency” table in the “Reference Tables” section below.

¹²¹³ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

¹²¹⁴ ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

$kWh_{EXISTdaily\max}$ = See “Existing Equipment Efficiency” table in the “Reference Tables” section below

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

ΔkW
 $= (\Delta kWh/HOURS) * CF.$

Early Replacement:

ΔkW for remaining life of existing unit:
 $= (\Delta kWh/HOURS) * CF.$

ΔkW for remaining measure life (i.e., measure life less the remaining life of existing unit):
 $= (\Delta kWh/HOURS) * CF.$

Where:

$HOURS$ = Full load hours.
= 5858.¹²¹⁵
 CF = Summer Peak Coincidence Factor for measure.
= 0.77.¹²¹⁶

¹²¹⁵ Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.
¹²¹⁶ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost ¹²¹⁷
The incremental cost for this time of sale measure is assumed to be \$0.¹²¹⁸ For early replacement the incremental costs are listed in the “Early Replacement Remaining Useful Life and Incremental Cost” table in the Reference Tables section below.

Measure Life
The measure life is assumed to be 12 years.¹²¹⁹

Operation and Maintenance Impacts
n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency

Product Volume (in cubic feet)	Refrigerator (kWhBASEdaily $\times$ max)

¹²¹⁷ Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigerator_v3.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum.
¹²¹⁸ Energy Star Calculator accessed April 25, 2017, which cites Energy Star research, 2014.
¹²¹⁹ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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Vertical Closed	
<i>Solid</i>	<i>VCS.SC.M*</i>
All volumes	0.05V+1.36
<i>Transparent</i>	<i>VCT.SC.M</i>
All volumes	0.1V+0.86
Horizontal Closed	
<i>Solid</i>	<i>HCS.SC.M</i>
All volumes	0.05V+0.91
<i>Transparent</i>	<i>HCT.SC.M</i>
All volumes	0.06V+0.37

Where V = Unit volume in cubic feet

* DOE Equipment Class designations relevant to ENERGY STAR eligible product scope
(1) Equipment family code (HCS= horizontal closed solid, HCT=horizontal closed transparent, VCS= vertical closed solid, VCT=vertical closed transparent).)
(2) Operating mode (SC=self-contained).)
(3) Rating Temperature (M=medium temperature (38 °F), L=low temperature (0 °F)).)

Time of Sale Energy Star Equipment Efficiency

Product Volume (in cubic feet)	Refrigerator (kWhEEdailymax)
Vertical Closed	
<i>Solid</i>	<i>VCS.SC.M*</i>
0 < V < 15	0.022V+0.97
15 ≤ V < 30	0.066V+0.31
30 ≤ V < 50	0.04V+1.09
50 ≤ V	0.024V+1.89
<i>Transparent</i>	<i>VCT.SC.M</i>

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Product Volume (in cubic feet)	Refrigerator ($kWh_{EEdaily_{max}}$)
$0 < V < 15$	$0.095V + 0.445$
$15 \leq V < 30$	$0.05V + 1.12$
$30 \leq V < 50$	$0.076V + 0.34$
$50 \leq V$	$0.105V - 1.111$
Horizontal Closed	
<i>Solid or Transparent</i>	<i>HCT.SC.M, HCS.SC.M</i>
All volumes	$0.05V + 0.28$

Where V = Unit volume in cubic feet

Existing Equipment Efficiency

Product Class	Refrigerator Energy when existing unit was manufactured before 03/26/2017 ¹²²⁰ ($kWh_{EXISTdaily_{max}}$)	Refrigerator Energy when existing unit was manufactured after 03/27/2017 ($kWh_{EXISTdaily_{max}}$)
Vertical Closed		
<i>Solid</i>	<i>VCS.SC.M</i>	<i>VCS.SC.M</i>
All volumes	$0.10V + 2.04$	$0.05V + 1.36$
<i>Transparent</i>	<i>VCT.SC.M</i>	<i>VCT.SC.M</i>
All volumes	$0.12V + 3.34$	$0.1V + 0.86$
Horizontal Closed		
<i>Solid</i>	<i>HCS.SC.M</i>	<i>HCS.SC.M</i>
All volumes	$0.10V + 2.04$	$0.05V + 0.91$
<i>Transparent</i>	<i>HCT.SC.M</i>	<i>HCT.SC.M</i>

¹²²⁰ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2010)..

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All volumes	$0.12V + 3.34$	$0.06V + 0.37$

Where V = Unit volume in cubic feet

Early Replacement Remaining Useful Life and Incremental Cost¹²²¹

Age of Existing Unit Being Replaced	Remaining Useful Life (RUL) ¹²²²	Incremental Cost of Measure $0 \leq V < 25$	Incremental Cost of Measure $25 \leq V$
0	11	\$ 592	\$ 1,289
1	10	\$ 549	\$ 1,195
2	9	\$ 505	\$ 1,099
3	8	\$ 459	\$ 1,000
4	7	\$ 412	\$ 898
5	7	\$ 412	\$ 898
6	6	\$ 364	\$ 793
7	5	\$ 315	\$ 685
8	5	\$ 315	\$ 685
9	4	\$ 264	\$ 575
10	4	\$ 264	\$ 575
11	4	\$ 264	\$ 575
12	4	\$ 264	\$ 575
13	3	\$ 212	\$ 461

¹²²¹ The early replacement cost factors in the time value of money with a net present value analysis, comparing a purchase today with a purchase at the end of remaining useful life. Net present value analysis using an inflation rate of 2.2% and a discount rate of 5%.

¹²²² Navigant analysis based on Weibull curve for refrigeration remaining useful life <https://aceee.org/files/proceedings/2010/data/papers/1977.pdf>

14	3	\$ 212	\$ 461
15	3	\$ 212	\$ 461
16	3	\$ 212	\$ 461
17	3	\$ 212	\$ 461
18	2	\$ 158	\$ 345
19	2	\$ 158	\$ 345
20	2	\$ 158	\$ 345
21	2	\$ 158	\$ 345
22	2	\$ 158	\$ 345
23	2	\$ 158	\$ 345
24	2	\$ 158	\$ 345
25	2	\$ 158	\$ 345
26	2	\$ 158	\$ 345
27	2	\$ 158	\$ 345
28	2	\$ 158	\$ 345
29	2	\$ 158	\$ 345

Where V = Unit volume in cubic feet

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Night Covers for Refrigerated Cases

Unique Measure Code(s): CI_RF_RF_NTCOV_0615

Effective Date: June 2015

End Date: TBD

Measure 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. Continuous curtains can be pulled down overnight while the store is closed, yielding significant energy savings.

Definition of Baseline Condition

In order for this characterization to apply, the baseline equipment is assumed to be a refrigerated case without a night cover.

Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be a refrigerated case with a continuous cover deployed during overnight periods. Characterization assumes covers are deployed for six hours daily.

Annual Energy Savings Algorithm

$$\Delta kWh = (LOAD / 12,000) * FEET * (3.516) / COP * ESF * 8,760.$$

$$\Delta kWh = 346.5 * FEET / COP.$$

Where:

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LOAD	= average refrigeration load per linear foot of refrigerated case without night covers deployed. = 1,500 BTU/h ¹²²³ per linear foot.
FEET	= linear (horizontal) feet of covered refrigerated case.
12,000	= conversion factor - BTU per ton cooling.
3.516	= conversion factor – Coefficient of Performance (COP) to kW per ton.
COP	= Coefficient of Performance of the refrigerated case. = assume 2.2 ¹²²⁴ , if actual value is unknown.
ESF	= Energy Savings Factor; reflects the percent reduction in refrigeration load due to the deployment of night covers = 9%. ¹²²⁵
8,760	= assumed annual operating hours of the refrigerated case.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0$ ¹²²⁶

¹²²³ Davis Energy Group, Analysis of Standard Options for Open Case Refrigerators and Freezers, May 11, 2004. Accessed on 7/7/10 <
http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Open_Case_Refrig.pdf>

¹²²⁴ Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.

¹²²⁵ Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case, Southern California Edison, August 8, 1997. Accessed on 7/7/10.
<http://www.sce.com/NR/rdonlyres/2AAEFF0B-4CE5-49A5-8E2C-3CE23B81F266/0/AluminumShield_Report.pdf>; Characterization assumes covers are deployed for six hours daily.

¹²²⁶ Assumed that the continuous covers are deployed at night; therefore no demand savings occur during the peak period.

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Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost for this retrofit measure is \$42 per linear foot of cover installed including material and labor.¹²²⁷

Measure Life

The expected measure life is assumed to be 5 years.¹²²⁸

Operation and Maintenance Impacts

n/a

¹²²⁷ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, California Public Utilities Commission, December 16, 2008
<http://deerresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip>

¹²²⁸ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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Anti-Sweat Heater Controls

Unique Measure Code(s): CI_RF_TOS_ASHC_0516
Effective Date: May 2016
End Date: TBD

Measure Description

Anti-sweat door heaters (ASDH) prevent condensation from forming on cooler and freezer doors. By installing a control device to turn off door heaters when there is little or no risk of condensation, significant energy savings can be realized. There are two commercially available control strategies – (1) ON/OFF controls and (2) micro pulse controls – that respond to a call for heating, which is typically determined using either a door moisture sensor or an indoor air temperature and humidity sensor to calculate the dew point. In the first strategy, the ON/OFF controls turn the heaters on and off for minutes at a time, resulting in a reduction in run time. In the second strategy, the micro pulse controls pulse the door heaters for fractions of a second, in response to the call for heating.

Both of these strategies result in energy and demand savings. Additional savings come from refrigeration interactive effects. When the heaters run less, they introduce less heat into the refrigerated spaces and reduce the cooling load.

Definition of Baseline Condition

In order for this characterization to apply, the baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door running 24 hours a day, seven days per week (24/7) with no controls installed.

Definition of Efficient Condition

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In order for this characterization to apply, the efficient equipment is assumed to be a door heater control on a commercial glass door cooler or refrigerator utilizing either ON/OFF or micro pulse controls.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_d * (\%ON_{NONE} - \%ON_{CONTROL}) * NUMdoors * HOURS * WHFe.$$

Where:

- kW_d* = connected load kW per connected door.
= If actual kW_d is unknown, assume 0.13 kW.¹²²⁹
- %ON_{NONE}* = Effective run time of uncontrolled ASDH.
= assume 90.7%.¹²³⁰
- %ON_{CONTROL}* = Effective run time of ASDH with controls.
= assume 58.9% for ON/OFF controls and 42.8% for micropulse controls.¹²³¹
- NUMdoors* = number of reach-in refrigerator or freezer doors controlled by sensor.
= Actual number of doors controlled by sensor.
- HOURS* = Hours of operation.
= 8,760.
- WHFe* = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment.

¹²²⁹ Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.
¹²³⁰ Ibid.
¹²³¹ Ibid.

= assume 1.25 for cooler and 1.50 for freezer applications.¹²³²

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = kW_d * WHFd * CF.$

Where:

- WHFd

= Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment.
= assume 1.25 for cooler and 1.50 for freezer.
- CF

= Summer Peak Coincidence Factor.
= If site specific CFs are unknown, use deemed estimates in the table below.¹²³³

Control Type	CF _{refrigerator}	CF _{freezer}
On/Off Controls	0.25	0.21
Micropulse Controls	0.36	0.30

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

¹²³² Ibid. Coincidence factors developed by dividing the PJM Summer Peak kW Savings for ASDH Controls from Table 52 of the referenced report (0.041 kW/door for on/off controls and 0.58 kW/door for micropulse controls) by the product of the average wattage of ASDH per connected door (0.13 kW) and the Waste Heat Factor for Demand for either a refrigerator or a freezer.
¹²³³ Ibid.

n/a

Incremental Cost

The incremental capital cost is \$994 for a door heater controller, \$123 for a cooler door, and \$219 for a freezer door¹²³⁴. Values include labor costs.

Measure Life

The expected measure life is assumed to be 12 years.¹²³⁵

Operation and Maintenance Impacts

n/a

¹²³⁴ Navigant. 2015. *Incremental Cost Study Phase Four, Final Report*. Burlington, MA.

¹²³⁵ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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Evaporator Fan Electronically-Commutated Motor (ECM) Retrofit

Unique Measure Code(s): CI_RF_RF_ECMFAN_0516
Effective Date: May 2016
End Date: TBD

Measure Description

Evaporator fans circulate air in refrigerated spaces by drawing air across the evaporator coil and into the space. Fans are found in both reach-in and walk-in coolers and freezers. Energy and demand savings for this measure are achieved by reducing motor operating power. Additional savings come from refrigeration interactive effects. Because electronically-commutated motors (ECMs) are more efficient and use less power, they introduce less heat into the refrigerated space compared to the baseline motors and result in a reduction in cooling load on the refrigeration system.

Definition of Baseline Condition

In order for this characterization to apply, the baseline condition is assumed to be an evaporator fan powered by a shaded pole (SP) motor that runs 24 hours a day, seven days per week (24/7) with no controls.

Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be an evaporator fan powered by an ECM that runs 24/7 with no controls.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_{hp} * HP * \% \Delta P * \% ON_{UC} * HOURS * WHFe.$$

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Where:

kW_{hp} = ECM connected load kW per horsepower.
= If actual kW_{hp} is unknown, assume 0.758 kW/hp.¹²³⁶

HP = Horsepower of ECM.
= Actual horsepower of ECM.

$\% \Delta_P$ = Percent change in power relative to ECM kW, calculated as the kW of the SP motor minus the kW of the ECM, divided by the kW of the ECM.
= If actual $\% \Delta_P$ is unknown, assume 157%.¹²³⁷

$\% ON_{UC}$ = Effective run time of uncontrolled motors.
= If actual $\% ON_{UC}$ is unknown, assume 97.8%.¹²³⁸

HOURS = Hours of operation.
= 8,760.

WHFe = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.
= assume 1.38 for cooler and 1.76 for freezer applications.¹²³⁹

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kW_{hp} * HP * WHFd * CF.$$

1236

Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

1237

Ibid.

1238

Ibid.

1239

Ibid.

Where:

WHFd

= Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.
= assume 1.38 for cooler and 1.76 for freezer applications. ¹²⁴⁰

CF

= Summer Peak Coincidence Factor.
= If site specific CFs are unknown, use 1.53. ¹²⁴¹

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost
The incremental capital cost is \$61. Values include labor costs. ¹²⁴²

Measure Life

¹²⁴⁰ Ibid.

¹²⁴¹ Ibid. Coincidence factors developed by dividing the PJM Peak Savings for EF Motors and Controls from Table 47 of the referenced report (1.607 for a refrigerator and 2.048 for a freezer by the product of the average ECM wattage per rated horsepower (0.758 kW/hp) and the Waste Heat Factor for Demand for either a refrigerator or a freezer. Note: the CF is greater than one because it is calculated relative to the wattage of the post-retrofit ECM motor as opposed to the existing SP motor.

¹²⁴² Based on a review of the Maine, Vermont, Illinois, and Wisconsin technical reference manuals, published incremental cost estimates for this measure range from \$25 to \$245. Assume the median cost of \$60 adjusted for inflation.

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The expected measure life is assumed to be 15 years.¹²⁴³

Operation and Maintenance Impacts

n/a

¹²⁴³ Energy & Resource Solutions (ERS). 2005. Measure Life Study: prepared for The Massachusetts Joint Utilities

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Evaporator Fan Motor Controls

Unique Measure Code(s): CI_RF_RF_EFCTRL_0516

Effective Date: May 2016

End Date: TBD

Measure Description

Evaporator fans circulate cool air in refrigerated spaces by drawing air across the evaporator coil and into the space. Uncontrolled, evaporator fans run 24 hours a day, seven days per week (24/7). Evaporator fan controls reduce fan run time or speed depending on the call for cooling, and therefore provide an opportunity for energy and demand savings. There are two commercially available strategies – (1) ON/OFF controls and (2) multispeed controls – that respond to a call for cooling. In the first strategy, the ON/OFF controls turn the motors on and off in response to the call for cooling, generating energy and demand savings as a result of a reduction in run time. In the second strategy, the multispeed controls change the speed of the motors in response to the call for cooling, saving energy and reducing demand by reducing operating power and run time (multispeed controls can also turn the motor off).

Additional savings come from the refrigeration interactive effects. Because fan controls reduce motor operating power and/or run time, they introduce less heat into the refrigerated space compared to uncontrolled motors and result in a reduction in cooling load on the refrigeration system.

Definition of Baseline Condition

In order for this characterization to apply, the baseline condition is assumed to be an evaporator fan powered by an uncontrolled ECM or SP motor that runs 24/7.

Definition of Efficient Condition

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In order for this characterization to apply, the efficient equipment is assumed to be an evaporator fan powered by an ECM or SP motor utilizing either ON/OFF or multispeed controls.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_{hp} * HP * (\%ON_{UC} - \%ON_{CONTROL}) * HOURS * WHFe$$

Where:

- kW_{hp}*

*= connected load kW per horsepower of motor.
= If actual kW_{hp} is unknown, assume 0.758 kW/hp for ECM and 2.088 kW/hp for SP motor.¹²⁴⁴*
- HP*

*= Horsepower of ECM or SP motor.
= Actual horsepower of ECM or SP motor.*
- %ON_{UC}*

*= Effective run time of uncontrolled motor
= If actual %ON_{UC} is unknown, assume 97.8%.¹²⁴⁵*
- %ON_{CONTROL}*

*= Effective run time of motor with controls.
= Assume 63.6% for ON/OFF style controls and 69.2% for multi-speed style controls.¹²⁴⁶*
- HOURS*

*= Hours of operation.
= 8,760.*
- WHFe*

= Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.

¹²⁴⁴ Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

¹²⁴⁵ Ibid.

¹²⁴⁶ Ibid.

= assume 1.38 for cooler and 1.76 for freezer applications.¹²⁴⁷

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kW_{hp} * HP * WHFd * CF$$

Where:

- WHFd

= Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.
= assume 1.38 for cooler and 1.76 for freezer applications.¹²⁴⁸
- CF

= Summer Peak Coincidence Factor.
= If site specific CFs are unknown, use 0.26.¹²⁴⁹

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

1247

Ibid.

1248

Ibid.

1249

Ibid. Coincidence factors developed by dividing the PJM Peak Savings for EF Motors and Controls from Table 47 of the referenced report by the product of the average baseline motor wattage per rated horsepower (0.758 kW/hp for ECM and 2.088 kW/hp for SP) and the Waste Heat Factor for Demand.

The incremental capital cost is \$532 for multispeed controls¹²⁵⁰. Value includes labor costs.

The actual measure installation cost for ON/OFF controls should be used (including materials and labor)¹²⁵¹.

Measure Life

The expected measure life is assumed to be 10 years.¹²⁵²

Operation and Maintenance Impacts

n/a

¹²⁵⁰ Navigant. 2015. *Incremental Cost Study Phase Four, Final Report*. Burlington, MA.

¹²⁵¹ Ibid. Navigant's research revealed that ON/OFF controls are typically only found in refrigeration management systems. These systems have capabilities beyond evaporator fan control, including controls for the compressor cycle, defrost cycle, door heaters, outdoor air economizer, and more. The cost of these systems is highly variable depending on capability and falls in the approximate range of \$500 - \$1,700.

¹²⁵² Energy & Resource Solutions (ERS). 2005. Measure Life Study: prepared for The Massachusetts Joint Utilities.

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Refrigeration Door Gasket Replacement

Unique Measure Code(s): CI_RF_TOS_RGasket_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure describes the replacement of damaged refrigeration door gaskets with new sealing gaskets for walk-in or reach-in refrigeration units in either an unconditioned space or in a conditioned space where the condensing unit is also in the conditioned space. A walk-in unit housed in a mechanically cooled space, but where the condenser is located outside is not eligible since the leak is acting as a localized air conditioner, reducing the load of the space cooling system.

Definition of Baseline Condition

The baseline condition is an old and/or damaged gasket with at least six inches of damage for reach-in units and at least two feet of damage for walk-in units.¹²⁵³

Definition of Efficient Condition

The efficient condition is a new complete gasket.

Annual Energy Savings

$$\Delta kWh = SPF_e * L$$

Where:

¹²⁵³ BPA sponsored Emerson study. "Study of Typical Gasket Deterioration", Feb 27, 2008, Emerson Design Services Network. <https://slideplayer.com/slide/4525301/>

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SPF_e = Annual Energy Savings per Foot of gasket, given in the table below.

Refrigeration Type	Energy Savings (kWh /foot) ¹²⁵⁴
Low Temp (Freezer) Reach-in	27.3
Med Temp (Cooler) Reach-in	18.2
Low Temp (Freezer) Walk-in	33.1
Med Temp (Cooler) Walk-in	18.0

L = total length of gasket being replaced, in feet. Note: This is independent of the damaged portion of gasket. If unknown, assume 15 feet for reach-in units and 20 feet for walk-in units.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = SPF_d * L$$

Where:
 SPF_d = Demand Savings per Foot of gasket

¹²⁵⁴ BPA sponsored Emerson study. “Study of Typical Gasket Deterioration”, Feb 27, 2008, Emerson Design Services Network. <https://slideplayer.com/slide/4525301/>.

Refrigeration Type	Peak Demand Reduction (kW /foot) ¹²⁵⁵
Low Temp (Freezer) Reach-in	0.001928
Med Temp (Cooler) Reach-in	0.000829
Low Temp (Freezer) Walk-in	0.001911
Med Temp (Cooler) Walk-in	0.000822

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure is assumed to be \$7 per linear foot for low-temp freezers and \$5 per linear foot for medium-temp coolers.¹²⁵⁶ This is for the full length replaced, not the length damaged.

Measure Life

¹²⁵⁵ Analysis of results from BPA sponsored Emerson study, "Study of Typical Gasket Deterioration", Feb 27, 2008, Emerson Design Services Network <https://slideplayer.com/slide/4525301/> and Pennsylvania TRM 2016.

¹²⁵⁶ BPA sponsored Emerson study. "Study of Typical Gasket Deterioration", Feb 27, 2008, Emerson Design Services Network. <https://slideplayer.com/slide/4525301/>

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The measure life is assumed to be 4 years.¹²⁵⁷

Operation and Maintenance Impacts

n/a

¹²⁵⁷ Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, California Public Utility Commission, February 2010.

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Hot Water End Use

C&I Heat Pump Water Heater

Unique Measure Code(s): CI_WT_TOS_HPCIHW_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of a Heat Pump water heater in place of a standard electric water heater. This measure applies to time of sale and new construction opportunities.

Definition of Baseline Condition

The baseline condition is a standard electric water heater.

Definition of Efficient Condition

The efficient condition is a heat pump water heater.

Annual Energy Savings Algorithm

$$\Delta kWh = (kBTU_{req} / 3.413) * ((1/EF_{base}) - (1/EF_{ee}))$$

Where:

$kBTU_{req}$ (Office)

= Required annual heating output of office (kBTU)

= 6,059.¹²⁵⁸

¹²⁵⁸ Assumes an office with 25 employees; According to 2003 ASHRAE Handbook: HVAC Applications, Office typically uses 1.0 gal/person per day.

<i>kBTU_req (School)</i>	<i>= Required annual heating output of school (kBTU)</i> <i>= 22,191.¹²⁵⁹</i>
<i>3.413</i>	<i>= Conversion factor from kBTU to kWh.</i>
<i>EF_{HP}</i>	<i>= Energy Factor of Heat Pump domestic water heater.</i> <i>= 2.0.¹²⁶⁰</i>
<i>EF_{base}</i>	<i>= Energy Factor of baseline domestic water heater.</i> <i>= 0.904.¹²⁶¹</i>
 <i>ΔkWh Office</i>	 <i>= (6,059 / 3.413) * ((1/0.904) – (1/2.0)).</i> <i>= 1076.2 kWh.</i>
 <i>ΔkWh School</i>	 <i>= (22,191 / 3.413) * ((1/0.904) – (1/2.0)).</i> <i>= 3941.4 kWh.</i>

Assumes an 80F temperature rise based on a typical hot water holding tank temperature setpoint of 140F and 60F supply water. Actual supply water temperature will vary by season and source.
Water heating requirement equation adopted from FEMP Federal Technology Alert: Commercial Heat Pump Water Heater, 2000.

¹²⁵⁹ Assumes an elementary school with 300 students; According to 2003 ASHRAE Handbook: HVAC Applications, Elementary School typically uses 0.6 gal/person per day of operation. Assumes 37 weeks of operation.
Assumes an 80F temperature rise based on a typical hot water holding tank temperature setpoint of 140F and 60F supply water. Actual supply water temperature will vary by season and source.
Water heating requirement equation adopted from FEMP Federal Technology Alert: Commercial Heat Pump Water Heater, 2000.

¹²⁶⁰ Efficiencies based on ENERGY STAR Residential Water Heaters, Final Criteria Analysis: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/WaterHeaterDraftCriteriaAnalysis.pdf

¹²⁶¹ Ibid.

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If the deemed “kBTU_req” estimates are not applicable, the following equation can be used to estimate annual water heating energy requirements:

$$kBTU\_req = GPD * 8.33 * 1.0 * WaterTempRise * 365 / 1000.$$

- Where:
- GDP = Average daily hot water requirements (gallons/day).
= Actual usage (Note: days when the building is unoccupied must be included in the averaging calculation).
 - 8.33 = Density of water (lb/gallon).
 - 1.0 = Specific heat of water (BTU/lb-°F).
 - WaterTempRise = Difference between average temperature of water delivered to site and water heater setpoint (°F).
 - 365 = Days per year.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

- Where:
- Hours (Office) = Run hours in office.
= 5885.¹²⁶²
 - Hours (School) = Run hours in school.
= 2218.¹²⁶³
 - CF (Office) = Summer Peak Coincidence Factor for office measure.

¹²⁶² Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.
¹²⁶³ Ibid.

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Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided below.¹²⁶⁶

Size	Efficiency Factor	Incremental Cost per Unit
40 Gallons	2	\$1,338
60 Gallons	2.2	\$2,253

Measure Life

The measure life is assumed to be 10 years.¹²⁶⁷

Operation and Maintenance Impacts

n/a

¹²⁶⁶ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 - 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

¹²⁶⁷ Vermont Energy Investment Corporation “Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status” November 2005.

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Pre-Rinse Spray Valves

Unique Measure Code(s): CI_WT_EREP_PRSPRY_0615

Effective Date: June 2015

End Date: TBD

Measure Description

All pre-rinse valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. They reduce water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The spray valves usually have a clip to lock the handle in the “on” position. Pre-rinse valves are inexpensive and easily interchangeable with different manufacturers’ assemblies. The primary impacts of this measure are water savings. Energy savings depend on the facility’s water heating fuel - if the facility does not have electric water heating, there are no electric savings for this measure; if the facility does not have fossil fuel water heating, there are no MMBTU savings for this measure.

Definition of Baseline Condition

The baseline equipment is assumed to be an existing spray valve with a flow rate of 3 gallons per minute.

Definition of Efficient Condition

The efficient equipment is assumed to be a pre-rinse spray valve with a flow rate of 1.6 gallons per minute, and with a cleanability performance of 26 seconds per plate or less.

Annual Energy Savings Algorithm

$$\Delta kWh = \Delta Water \times HOT\% \times 8.33 \times (\Delta T) \times (1/EFF) / 3413.$$

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Where:

$\Delta Water$ = Water savings (gallons); see calculation in “Water Impact” section below.

$HOT\%$ = The percentage of water used by the pre-rinse spray valve that is heated.
= 69%.¹²⁶⁸

8.33 = The energy content of heated water (BTU/gallon/°F).

ΔT = Temperature rise through water heater (°F).
= 70.¹²⁶⁹

EFF = Water heater thermal efficiency.
= 0.97.¹²⁷⁰

3413 = Factor to convert BTU to kwh.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0$

Annual Fossil Fuel Savings Algorithm

$\Delta MMBTU = \Delta Water \times HOT\% \times 8.33 \times (\Delta T) \times (1/EFF) \times 10^{-6}$

Where:

¹²⁶⁸ Measures and Assumptions for DSM Planning (2009). Navigant Consulting. Prepared for the Ontario Energy Board. This factor is a candidate for future improvement through evaluation.

¹²⁶⁹ Engineering judgment; assumes typical supply water temperature of 70 °F and a hot water storage tank temperature of 140 °F.

¹²⁷⁰ Federal Standards.
http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/51

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EFF = Water heater thermal efficiency.
= 0.75¹²⁷¹.
10⁻⁶ = Factor to convert BTU to MMBTU.

Annual Water Savings Algorithm

$\Delta Water = (FLO_{base} - FLO_{eff}) \times 60 \times HOURS_{day} \times 365$

Where :

$\Delta Water$ = Annual water savings (gal).
 FLO_{base} = The flow rate of the baseline spray nozzle.
= 3 gallons per minute.
 FLO_{eff} = The flow rate of the efficient equipment.
= 1.6 gallons per minute.
60 = minutes per hour.
365 = days per year.
HOURS = Hours used per day – depends on facility type as below:¹²⁷²

Facility Type	Hours of Pre-Rinse Spray Valve Use per Day (HOURS)
Full Service Restaurant	4
Other	2
Limited Service (Fast Food) Restaurant	1

¹²⁷¹ IECC 2006. Performance requirement for gas water heaters.
¹²⁷² Hours estimates based on PG&E savings estimates, algorithms, sources (2005). Food Service Pre-Rinse Spray Valves

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Incremental Cost

The actual measure installation cost should be used (including material and labor).

Measure Life

The measure life is assumed to be 5 years.¹²⁷³

Operation and Maintenance Impacts

n/a

¹²⁷³ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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High Efficiency Commercial Gas Storage Water Heater >75kBtu

Unique Measure Code(s): CI_WT_TOS_GASHW_HI_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure applies to the installation of stand-alone, gas-fired, commercial storage water heaters with an input rating of >75,000 BTU/hour and <4,000 Btus/hr per gallon of stored water, that meet or exceed ENERGY STAR criteria. It is not intended for equipment that delivers process or space heating hot water. The high efficiency unit would be installed at time of sale instead of a new unit rated at the minimum federal efficiency standard.

Definition of Baseline Condition

The baseline condition is a new conventional, commercial gas storage water heater, >75kBtu meeting prevailing federal code minimum efficiency standards¹²⁷⁴, effective after October 9, 2015. See Efficiency Criteria Table below.

Definition of Efficient Condition

The installed efficient equipment is a direct fired, stand-alone gas water heater >75kBtu input, meeting or exceeding ENERGY STAR v2.0 specifications¹²⁷⁵ effective October 1, 2018. See Efficiency Criteria Table below.

¹²⁷⁴ Federal minimum standards for standby loss and TE [CFR Title 10 → Chapter II → Subchapter D → Part 431 Subpart G](#)

¹²⁷⁵ [ENERGY STAR Commercial Water Heater Key Product Criteria](#)

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Commercial Gas Storage Water Heater >75kBtu, Efficiency Criteria			
Condition	Equipment Description	Maximum Standby Loss (Btu/hr)	Minimum Thermal Efficiency (TE)
Baseline	Gas-fired storage water heater meeting prevailing federal code	$IR/800 + 110 * (Vs^{.5})$	80%
Efficient ¹²⁷⁶	Gas-fired storage water heaters meeting ENERGY STAR criteria	$\leq 0.84 * [IR/800 + 110 * (Vs^{.5})]$	$\geq 94\%$

Annual Fossil Fuel Savings Algorithm
Annual MMBTU savings is the sum of standby loss savings and thermal efficiency savings.

$$\Delta \text{MMBTu} = ((IR/800 + 110 * (Vs^{.5})) - (.84 * IR/800 + 110 * (Vs^{.5})) * 8,760 / 1,000,000) + (\text{MMBTU}/\text{yr}_{\text{act}} * (1 - (TE_{\text{base}} / TE_{\text{eff}})))$$

Where:

IR = Input rate (BTU/hr) of efficient WH
Note: IR of the baseline unit and efficient units must be the same for correct savings.

Vs = rated storage volume (gallons) of new, efficient water heater

TE_{base} = Thermal Efficiency of baseline unit

TE_{eff} = Thermal Efficiency of efficient unit

MMBTU/yr_{act} = existing annual water heating energy consumed, actual (measured or calculated)

8,760 = hours in a year

¹²⁷⁶ [ENERGY STAR Commercial Water Heater eligibility criteria v2.0](#)

1,000,000 = conversion from BTU to MMBTU

The following example is shown to calculate the annual energy savings of a new energy efficient, direct fired, 100 gallon, 150kBtu stand-alone gas water heater with a TE of 96% and standby loss rated at 1,000 Btu/hr as compared minimum federal efficiency standard of 80% TE installed at time of natural replacement. The existing water heater was estimated to consume 200 MMBtu/year.

Standby Loss of baseline unit (Max)

$$\begin{aligned}\text{Btu/hr} &= \text{IR} / 800 + 110 * (\text{Vs}^{.5}) \\ &= 150,000/800 + 110 * (100^{.5}) \\ &= 1,287.5 \text{ Maximum allowable}\end{aligned}$$

Standby Loss of efficient unit (Max)

$$\begin{aligned}\text{Btu/hr} &= .84 * \text{IR} / 800 + 110 * (\text{Vs}^{.5}) \\ &= .84 * 150,000/800 + 110 * (100^{.5}) \\ &= 1,081.5 \text{ Maximum allowable} \\ &= 1,000 \text{ as rated (rated takes precedence)}\end{aligned}$$

Annual Standby Loss Savings

$$\begin{aligned}\Delta \text{MMBtu} &= (\text{standby loss of efficient unit} - \text{standby loss of baseline unit}) * 8,760 / \\ 1,000,000 & \\ &= (1,287.5 - 1,000) * 8,760 / 1,000,000 \\ &= 2.5 \text{ MMBtu/yr savings}\end{aligned}$$

Annual Thermal Efficiency Savings

$$\begin{aligned}\Delta \text{MMBtu} &= \text{MMBtu/yr}_{\text{act}} * (1 - (\text{TE}_{\text{base}} / \text{TE}_{\text{eff}})) \\ &= 200 * (1 - (.80 / .96)) \\ &= 33.3\end{aligned}$$

Total Annual Savings

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Total Annual MMBtu Savings = Annual Standby Loss Savings + Annual Thermal Efficiency Savings
= 2.5 + 33.3
= 35.8 MMBtu

Incremental Cost

\$1,510¹²⁷⁷

Measure Life

The measure life is assumed to be 10 years¹²⁷⁸

¹²⁷⁷ NEEP Water Heating, Boiler and Furnace Cost Study September 2018, adjusted to 2019 dollars, 50 gallon, 100 MBH

¹²⁷⁸ [EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018](#)

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High Efficiency Commercial Gas Storage Water Heater ≤75kBtu

Unique Measure Code(s): CI_WT_TOS_GASHW_HI_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure applies to the installation of stand-alone, gas-fired, storage water heaters used in commercial applications with an input rating of ≤75,000 BTU/hour that meet or exceed ENERGY STAR criteria. It is not intended for equipment that delivers process or space heating hot water. The high efficiency unit would be installed at time of sale instead of a new unit rated at the minimum federal standard.

Definition of Baseline Condition

The baseline condition is a new, conventional gas-fired storage water heater, ≤75kBtu input, with a rated storage volume between 20 and 100 gallons, meeting prevailing federal code minimum efficiency standards¹²⁷⁹ for consumer products (due to ≤75kBtu input rating) referencing the Uniform Energy Factor (UEF) energy performance criteria. This specification became effective December 29, 2016¹²⁸⁰.

Definition of Efficient Condition

The installed efficient equipment is a stand-alone, gas-fired storage water heater, ≤75kBtu input, with a rated storage volume between 20 and 100 gallons, that meets or exceeds ENERGY

¹²⁷⁹ [Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32](#)

¹²⁸⁰ [Docket No. EERE-2015-BT-TP-0007](#)

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STAR water heater requirements Version 3.2¹²⁸¹, referencing Energy Factor (EF) or Uniform Energy Factor¹²⁸² (UEF) energy performance criteria, effective April 16, 2015.

Commercial Gas Storage Water Heater ≤75kBtu Efficiency Criteria						
Condition	Storage Volume (Vs)	Min. Energy Factor (EF)	Min. Uniform Energy Factor (UEF) based on hot water draw pattern			
			very small 10 GPD	low 38 GPD	medium 55 GPD	high 84 GPD
Baseline (min fed standard)	≥20 and ≤55 gal	0.675-(0.0015 * Vs)	0.3456 – (0.0020 * Vs)	0.5982 – (0.0019 * Vs)	0.6483 – (0.0017 * Vs)	0.692 – (0.0013 * Vs)
	>55 gal and ≤100 gal	0.8012-(0.00078 * Vs)	0.6470 – (0.0006 * Vs)	0.7689 – (0.0005 * Vs)	0.7897 – (0.0004 * Vs)	0.8072 – (0.0003 * Vs)
Efficient	≤55 gal	≥0.67	NA	NA	≥0.64	≥0.68
	>55 gal	≥0.77	NA	NA	≥0.78	≥0.80

Determining Draw Pattern

The relevant hot water draw pattern is specific to the installed location. If actual draw pattern is not known, it can be estimated from the water heater’s first hour rating¹²⁸³ per table below. If first hour rating is unknown, use medium draw pattern with rated storage capacity ≤50 gallons, and high draw pattern if >50 gallons.¹²⁸⁴

Draw Pattern based on First Hour Rating	
First Hour Rating	Draw Pattern

¹²⁸¹ [ENERGY STAR® v3.2 Program Requirements for Residential Water Heaters](#)

¹²⁸² [Title 10 → Chapter II → Subchapter D → Part 430 Appendix E](#)

¹²⁸³ [CFR part 430 App E 5.4.1](#)

¹²⁸⁴ [Title 10 → Chapter II → Subchapter D → Part 430 → E → Table 5.4.1](#)

<18 gallons	Very Small
=18 and <51 gallons	Low
=51 and <75 gallons	Medium
≥75 gallons	High

Annual Fossil Fuel Savings Algorithm, UEF Method

$\Delta\text{MMBTU} = \text{MMBTu/yr}_{\text{act}} * \text{UEF}_{\text{base}} * (1/\text{UEF}_{\text{base}} - 1/\text{UEF}_{\text{eff}})$

Annual Fossil Fuel Savings Algorithm, EF Method

$\Delta\text{MMBTU} = \text{MMBTu/yr}_{\text{act}} * \text{EF}_{\text{base}} * (1/\text{EF}_{\text{base}} - 1/\text{EF}_{\text{eff}})$

Where:

$\text{MMBTu/yr}_{\text{act}}$ = existing annual water heating energy consumed, actual (measured or calculated)

UEF_{base} = Uniform Energy Factor of baseline water heater
= as-rated based on draw pattern OR
If unknown, calculate using values from “Draw Pattern based on First Hour Rating” table and additional algorithm from “Efficiency Criteria” table above.

UEF_{eff} = Uniform Energy Factor of efficient water heater

EF_{base} = Energy Factor of baseline water heater

EF_{eff} = Energy Factor of efficient water heater

V_s = rated storage volume (gallons)

Example to calculate the annual energy savings of a new energy efficient direct fired, 55 gallon stand-alone gas water heater with a UEF of .68 and an estimated annual consumption of 50MMBTU/yr.

This water draw pattern is known to be high. The baseline unit is the same size and meets the minimum federal standard UEF of .62 as calculated from the Efficiency Criteria table above.

$\Delta\text{MMBTU} = 50 \text{ MMBtu/yr}_{\text{act}} * .62 * (1/.62 - 1/.68)$
 $= 31 * .14$

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= 4.41 MMBtu/yr savings

Incremental Cost

\$377¹²⁸⁵

Measure Life

The measure life is assumed to be 13 years¹²⁸⁶

¹²⁸⁵ NEEP Water Heating, Boiler and Furnace Cost Study September 2018, adjusted to 2019 dollars, 50 gallon, 40 MBH

¹²⁸⁶ [EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018 \(average\)](#)

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Commercial Faucet Aerators

Unique Measure Code(s): CI WT FCT AERT
Effective Date: July 2024
End Date: TBD

Measure Description

This measure relates to the direct installation of a low flow faucet aerator in a commercial building. Expected applications include small business, office, restaurant, or motel. Health care-specific inputs are defined for Laminar Flow Restrictor (LFR) devices.

For multifamily or senior housing, the residential low flow faucet aerator should be used.

Definition of Baseline Condition

The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or more, or a standard kitchen faucet aerator rated at 2.75 GPM or more. For LFR devices, the baseline condition is assumed to be no aerator at all, due to the contamination risk caused by faucet aerators in health care facilities and the baseline flow rate is assumed to be 3.74 GPM.¹²⁸⁷

Definition of Efficient Condition

For this measure the installed equipment must be an energy efficient faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. For LFR devices, the installed equipment must be a device rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

¹²⁸⁷ [Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.](#)

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Annual Energy Savings Algorithm

$$\frac{\Delta kWh}{EPG\ electric * ISR} = \%ElectricDHW * ((GPM\ base - GPM\ low) / GPM\ base) * Usage *$$

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Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

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GPM base = Average flow rate, in gallons per minute, of the baseline faucet "as-used"
= 1.39 GPM¹²⁸⁸ or custom based on metering studies.
= Baseline for LFRs¹²⁸⁹ = 3.10 GPM

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GPM low = Average flow rate, in gallons per minute, of the low-flow faucet "as-used"
= 0.94 GPM¹²⁹⁰ or custom based on metering studies.

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¹²⁸⁸ DeOreo, B., and P. Mayer. Residential End Uses of Water Study Update. Forthcoming. ©2015 Water Research Foundation. Reprinted With Permission.

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¹²⁸⁹ 2008, 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. Page 1-265.

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¹²⁹⁰ Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7. This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

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= Baseline for LFRs¹²⁹¹ = 2.09 GPM

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Usage = Estimated usage of mixed water per faucet. If unknown use defaults from the table below:

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Building Type	Gallons hot water per unit per day ¹²⁹¹ (A)	Unit	Estimated % hot water from faucets ¹²⁹¹ (B)	Multplier ¹²⁹¹ (C)	Unit	Days per year (D)	Ann gallons mixed water per faucet (A*B*C*D)
Small Office	1	person	100%	10	employees per faucet	250	2,500
Large Office	1	person	100%	45	employees per faucet	250	11,250
Fast Food Rest	0.7	meal/day	50%	75	meals per faucet	365	9,581
Sit-Down Rest	2.4	meal/day	50%	36	meals per faucet	365	15,768
Retail	2	employee	100%	5	employees per faucet	365	3,650
Grocery	2	employee	100%	5	employees per faucet	365	3,650
Warehouse	2	employee	100%	5	employees per faucet	250	2,500
Elementary School	0.6	person	50%	50	students per faucet	200	3,000
Jr High/High School	1.8	person	50%	50	students per faucet	200	9,000
Health	90	patient	25%	2	Patients per faucet	365	16,425
Motel	20	room	25%	1	faucet per room	365	1,825
Hotel	14	room	25%	1	faucet per room	365	1,278
Other	1	employee	100%	20	employees per faucet	250	5,000

EPG Electric = Energy per gallon of mixed water used by faucet (electric water heater)

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¹²⁹¹ Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

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$$= (8.33 * 1.0 * (WaterTemp - SupplyTemp)) / (RE\_electric * 3412)$$
$$= 0.0879 \text{ kWh/gal for Bath, } 0.1054 \text{ kWh/gal for Kitchen, } 0.1477 \text{ kWh/gal for LFRs, } 0.1004 \text{ kWh/gal for unknown}$$

WaterTemp = Assumed temperature of mixed water
= 86°F for Bath, 93°F for Kitchen, 91°F for Unknown¹²⁹², 110°F for health care facilities

SupplyTemp = Assumed temperature of water entering the building

RE Electric = Recovery efficiency of electric water heater. If unknown use 98%

ISR = In service rate of faucet aerators dependant on install method as listed in table below

Selection	ISR
Direct Install - Deemed	0.95
Efficiency Kits - Default	0.50
Leave-Behind Kit	0.91

Summer Coincident Peak kW Savings Algorithm

¹²⁹² Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7*93)+(0.3*86)=0.91.

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$\Delta kW = 0$

Annual Fossil Fuel Savings Algorithm

$$\frac{\Delta \text{MMBtu}}{\text{Therms}} = \frac{\% \text{FossilDHW} * ((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \text{Usage} * \text{EPG}_{\text{gas}} * \text{ISRW}_{\text{Water}} * \text{HOT\%} * 8.33 * (\Delta T) * (1 / \text{EFF}) * 10^{-6}}{}$$

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Where:

$\text{RE}_{\text{gasEFF}} = \text{Water heater thermal efficiency}$
 $\text{Recovery efficiency of gas water heater.}$

$$= 67\%^{1293} 0.75^{1294}$$

 $\% \text{FossilDHW} = \text{proportion of water heating supplied by fossil fuel heating}$

DHW fuel	%Fossil DHW
Electric	0%
Fossil Fuel	100%
Unknown	72.4%

¹²⁹³ Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.

¹²⁹⁴ IECC 2006. Performance requirement for gas water heaters.

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$$\begin{aligned} EPG_{gas} &= \text{Energy per gallon of mixed water used by faucet (gas water heater)} \\ &= (8.33 * 1.0 * (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE}_{gas} * 100,000) \\ &= 0.0044 \text{ Therm/gal for Bath, } 0.0053 \text{ Therm/gal for Kitchen, } \\ &\quad 0.0074 \text{ Therm/gal for LFRs, } 0.0050 \text{ Therm/gal for unknown} \\ 10^{-6} &= \text{Factor to convert BTU to MMBTU.} \end{aligned}$$

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Annual Water Savings Algorithm

$$\Delta \text{Water (gallons)} = ((\text{GPM}_{base} - \text{GPM}_{low}) / \text{GPM}_{base}) * \text{Usage} * \text{ISR}$$

$$\text{Variables as defined above. } \Delta \text{Water} = (\text{FLO}_{base} - \text{FLO}_{eff}) * 60 * \text{HOURS}_{day} * 365$$

Where :

ΔWater = Annual water savings (gal).

FLO_{base} = The flow rate of the baseline spray nozzle.

= 3 gallons per minute.

FLO_{eff} = The flow rate of the efficient equipment.

= 1.6 gallons per minute.

60 = minutes per hour.

365 = days per year.

HOURS = Hours used per day — depends on facility type as below.⁴²⁹⁵

⁴²⁹⁵ Hours estimates based on PG&E savings estimates, algorithms, sources (2005). Food Service Pre-Rinse Spray Valves

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Facility Type	Hours of Pre Rinse Spray Valve Use per Day (HOURS)
Full Service Restaurant	4
Other	2
Limited Service (Fast Food) Restaurant	1

Incremental Cost

The actual measure installation cost should be used (including material and labor).

Measure Life

The measure life is assumed to be 105 years.¹²⁹⁶

Operation and Maintenance Impacts

n/a

¹²⁹⁶ As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. 2008 Database for Energy Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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Low Flow Showerheads

Unique Measure Code(s): CI WT ~~EREP PRSPRY 0615LF~~ SHWRHEAD

Effective Date: June 2015

End Date: TBD

Measure Description

~~A~~This measure relates to the direct installation of a low flow showerhead in a commercial building. Expected applications include small business, office, restaurant, or small motel. For multifamily or senior housing, the residential low flow showerhead should be used. ~~It pre-rinse valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. They reduce water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The spray valves usually have a clip to lock the handle in the "on" position. Pre-rinse valves are inexpensive and easily interchangeable with different manufacturers' assemblies. The primary impacts of this measure are water savings. Energy savings depend on the facility's water heating fuel – if the facility does not have electric water heating, there are no electric savings for this measure; if the facility does not have fossil fuel water heating, there are no MMBTU savings for this measure.~~

Definition of Baseline Condition

~~The baseline equipment is assumed to be an existing spray valve with a flow rate of 3 gallons per minute. Showerhead rated at 2.5 GPM.~~

Definition of Efficient Condition

The installed equipment must be an energy efficient showerhead rated at 2.0 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture

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basis. efficient equipment is assumed to be a pre-rinse spray valve with a flow rate of 1.6 gallons per minute, and with a cleanability performance of 26 seconds per plate or less.

Annual Energy Savings Algorithm

$$\Delta kWh = \%ElectricDHW * ((GPM\_base * L\_base - GPM\_low * L\_low) * NSPD * 365.25) * EPG\_electric * ISR\_Water * HOT\% * 8.33 * (\Delta T) * (1/EFF) / 3413.$$

- Where:
- %ElectricDHW = proportion of water heating supplied by electric resistance heating
= 1 if electric DHW; 0 if fuel DHW; if unknown, assume 27.6%
 - GPM_base = Flow rate of baseline showerheads
 - GPM_low = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaluations deviate from rated flows, see table below

Rated Flow
2.0 GPM
1.75 GPM
1.5 GPM
Custom or Actual

<u>L base</u>	= Shower length in minutes with baseline showerhead
	= 8.2. ¹²⁹⁷
<u>L low</u>	= Shower length in minutes with baseline showerhead
	= 8.2. ¹²⁹⁸
<u>NSPD</u>	= Estimated number of showers taken per day for one showerhead
<u>ΔWater</u>	= Water savings (gallons); see calculation in “Water Impact” section below.
<u>EPG electric</u>	= Energy per gallon of hot water supplied by electric
	= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE electric * 3412)
	= (8.33 * 1.0 * (101 – 50.7)) / (0.98 * 3412)
	= 0.125 kWh/gal HOT% = The percentage of water used by the pre-rinse spray valve that is heated.
	= 69%. ¹²⁹⁹
<u>8.33</u>	= The energy content of heated water (BTU/gallon/°F).
<u>ShowerTemp</u>	= Assumed temperature of water

¹²⁹⁷ Measures and Assumptions for DSM Planning (2009). Navigant Consulting. Prepared for the Ontario Energy Board. This factor is a candidate for future improvement through evaluation. Representative value from sources 1, 2, 3, 4, 5, and 6 (See Source Table at end of measure section).

¹²⁹⁸ Set equal to L base. Measures and Assumptions for DSM Planning (2009). Navigant Consulting. Prepared for the Ontario Energy Board. This factor is a candidate for future improvement through evaluation.

¹²⁹⁹ Measures and Assumptions for DSM Planning (2009). Navigant Consulting. Prepared for the Ontario Energy Board. This factor is a candidate for future improvement through evaluation.

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$$\frac{(\text{°F})}{\text{°F}} = \frac{101\text{°F AT}}{\text{°F}} = \text{Temperature rise through water heater}$$

$$\frac{\text{EFFRE}_{\text{electric}}}{\text{EFFRE}_{\text{electric}}} = \frac{70^{1300}}{\text{Water heater thermal efficiency}} = \text{Recovery efficiency of electric water heater.}$$

$$\frac{0.987^{1301}}{3413} = \text{Factor to convert BTU to kwh.}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0$$

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBTU} = \% \text{FossilDHW} * ((\text{GPM}_{\text{base}} * \text{L}_{\text{base}} - \text{GPM}_{\text{low}} * \text{L}_{\text{low}}) * \text{NSPD} * 365.25) * \text{EPG}_{\text{gas}} \Delta \text{Water} \times \text{HOT} \% \times 8.33 \times (\Delta T) \times (1/\text{EFF}) \times 10^{-6}$$

Where:

$$\% \text{FossilDHW} = \text{proportion of water heating supplied by fossil fuel heating}$$

¹³⁰⁰ Engineering judgment; assumes typical supply water temperature of 70°F and a hot water storage tank temperature of 140°F.

¹³⁰¹ Electric water heaters have recovery efficiency of 98%, as sourced from available products on the AHRI Certification Directory. Federal Standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/54

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DHW Fuel	%Fossil DHW
Electric	0%
Fossil Fuel	100%
Unknown	72.4%

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$EPG_{gas} = \text{Energy per gallon of hot water supplied by gas}$
 $= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_{gas} * 100,000)$
 $= 0.0063 \text{ therm/gal}$

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$\text{Other variables as defined above } EFF = \text{Water heater thermal efficiency.}$

$= 0.75^{1302}$
 $10^{-6} = \text{Factor to convert BTU to MMBTU.}$

Annual Water Savings Algorithm

$\Delta Water = ((GPM_{base} * L_{base} - GPM_{low} * L_{low}) * NSPD * 365.25)$
 $FLO_{base} - FLO_{eff} \times 60 \times HOURS_{day} \times 365$

$\text{Other variables as defined above}$

Where :
 $\Delta Water = \text{Annual water savings (gal).}$
 $FLO_{base} = \text{The flow rate of the baseline spray nozzle.}$
 $= 3 \text{ gallons per minute.}$
 $FLO_{eff} = \text{The flow rate of the efficient equipment.}$
 $= 1.6 \text{ gallons per minute.}$

¹³⁰² IECC 2006. Performance requirement for gas water heaters.

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60 = minutes per hour.

365 = days per year.

HOURS = Hours used per day — depends on facility type as below.¹³⁰³

<u>Facility Type</u>	<u>Hours of Pre Rinse Spray Valve Use per Day (HOURS)</u>
<u>Full Service Restaurant</u>	<u>4</u>
<u>Other</u>	<u>2</u>
<u>Limited Service (Fast Food) Restaurant</u>	<u>1</u>

Incremental Cost

The actual full install cost (including labor) should be used. If unknown, assume \$12 per showerhead. The actual measure installation cost should be used (including material and labor).

Measure Life

The measure life is assumed to be 105 years.¹³⁰⁴

Operation and Maintenance Impacts

¹³⁰³ Hours estimates based on PG&E savings estimates, algorithms, sources (2005). Food Service Pre-Rinse Spray Valves

¹³⁰⁴ Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family. 2008 Database for Energy Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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Appliance End Use

Commercial Clothes Washer

Unique Measure Code(s): CI_LA_TOS_CCWASH_0516
Effective Date: May 2016
End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a commercial clothes washer (i.e., soft-mounted front-loading or soft-mounted top-loading clothes washer that is designed for use in applications in which the occupants of more than one household will be using the clothes washer, such as multi-family housing common areas and coin laundries) exceeding the ENERGY STAR minimum qualifying efficiency standards presented below:¹³⁰⁵

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
ENERGY STAR	>= 2.2	<= 4.5

The Modified Energy Factor (MEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity; the higher the number, the greater the efficiency.

¹³⁰⁵ U.S. EPA. 2015. ENERGY STAR® Program Requirements Product Specification for Clothes Washers Eligibility Criteria Version 7.1

The Water Factor (WF) is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

Definition of Baseline Condition

The baseline efficiency is determined according to the Modified Energy Factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. The federal baseline MEF as of May 2016 is 1.60 for top loading units and 2.00 for front loading units. Beginning January 1, 2018, the federal standards increase to 1.35 for top loading units and remain 2.00 for front loading units.

Definition of Efficient Condition

The efficient condition is a clothes washer meeting the ENERGY STAR efficiency criteria presented above.

Annual Energy Savings Algorithm

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{DHW} + \Delta kWh_{DRYER}$$

$$\Delta kWh_{CW} = (kWh_{UNIT, BASE} - kWh_{UNIT, EE}) * \%CW$$

$$\Delta kWh_{DHW} = (kWh_{UNIT, BASE} - kWh_{UNIT, EE}) * \%DHW * DHW_{ELEC}$$

$$\Delta kWh_{DRYER} = [(kWh_{TOTAL, BASE} - kWh_{TOTAL, EE}) - (kWh_{UNIT, BASE} - kWh_{UNIT, EE})] * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE\_MOD} * DRYER_{ELEC}$$

$$kWh_{UNIT, i} = kWh_{UNIT\_RATED, i} * Ncycles / Ncycles\_ref$$

$$kWh_{TOTAL, i} = Capacity / MEF_i * Ncycles$$

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Where

- i

= Subscript denoting either baseline (“BASE”) or efficient (“EE”) equipment.
- ΔkWh_{CW}

= Clothes washer machine electric energy savings.
- ΔkWh_{DHW}

= Water heating electric energy savings.
- ΔkWh_{DRYER}

= Dryer electric energy savings.
- $kWh_{UNIT, BASE}$

= Conventional unit electricity consumption exclusive of required dryer energy.
- $kWh_{UNIT, EE}$

= ENERGY STAR unit electricity consumption exclusive of required dryer energy.
- $kWh_{TOTAL, BASE}$

= Conventional unit electricity consumption inclusive of required dryer energy (assuming electric dryer).
- $kWh_{TOTAL, EE}$

= ENERGY STAR unit electricity consumption inclusive of required dryer energy (assuming electric dryer).
- $kWh_{UNIT, RATED, BASE}$

= Conventional rated unit electricity consumption.
= If actual value unknown, assume 241 kWh/yr.¹³⁰⁶
- $kWh_{UNIT, RATED, EE}$

= Efficient rated unit electricity consumption.
= If actual value unknown, assume 97 kWh/yr.¹³⁰⁷
- $\%CW$

= Percentage of unit energy consumption used for clothes washer operation.
= If unknown, assume 20%.¹³⁰⁸
- $\%DHW$

= Percentage of unit energy consumption used for water heating.

¹³⁰⁶ U.S. EPA. 2016. Savings Calculator for ENERGY STAR Qualified Appliances. Accessed March 7, 2016.
http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

¹³⁰⁷ Ibid.

¹³⁰⁸ Ibid.

DHW_{ELEC} = If unknown, assume 80%.¹³⁰⁹
= 1 if electric water heating; 0 if gas water heating.
MEF_{BASE} = Modified Energy Factor of baseline unit.
= Values provided in table below.
MEF_{EE} = Modified Energy Factor of efficient unit.
= Actual. If unknown assume average values provided below.
Capacity = Clothes washer capacity (cubic feet).
= Actual. If capacity is unknown assume average 3.43 cubic feet.¹³¹⁰

Efficiency Level	Modified Energy Factor (MEF)	
	Front Loading	Top Loading
Federal Standard	On or After January 1, 2018	
	>= 2.00	>= 1.35
ENERGY STAR	>= 2.20	

Ncycles = Number of cycles per year.
= If actual value unknown, assume 1,241 for multifamily applications and 2,190 for landromats.¹³¹¹
Ncycles_ref = Reference number of cycles per year.

¹³⁰⁹ Ibid.
¹³¹⁰ Based on the average commercial clothes washer volume of all units meeting ENERGY STAR V7.1 criteria listed in the ENERGY STAR database of certified products accessed on 03/07/2016. <https://www.energystar.gov/productfinder/product/certified-commercial-clothes-washers/results>.
¹³¹¹ U.S. EPA. 2016. Savings Calculator for ENERGY STAR Qualified Appliances. Accessed March 7, 2016. http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Hours = Assumed Run hours of Clothes Washer.
= 265. ¹³¹⁵

¹³¹⁵ Metered data from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Appliance Rebate Program.” March 21, 2014, page 36. This data applies to residential applications. In the absence of metered data specific to multifamily common area and commercial laundromat applications, this coincidence value is

CF = Summer Peak Coincidence Factor for measure
= 0.029.¹³¹⁶

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = \Delta MMBTU_{DHW} + \Delta MMBTU_{DRYER}$$

$$\Delta MMBTU_{DHW} = (kWh_{UNIT, BASE} - kWh_{UNIT, EE}) * \%DHW / DHW_{EFF} * MMBTU\_convert * DHW_{GAS}$$

$$\Delta MMBTU_{DRYER} = [(kWh_{TOTAL, BASE} - kWh_{TOTAL, EE}) - (kWh_{UNIT, BASE} - kWh_{UNIT, EE})] * MMBTU\_convert * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE\_MOD} * DRYER_{GAS, CORR} * DRYER_{GAS}$$

Where:

$\Delta MMBTU_{DHW}$ = Water heating gas energy savings

$\Delta MMBTU_{DRYER}$ = Dryer gas energy savings

DHW_{EFF} = Gas water heater efficiency.

= If actual unknown, assume 75%.

$MMBTU\_convert$ = Conversion factor from kWh to MMBTU.

= 0.003413.

DHW_{GAS} = 1 if gas water heating; 0 if electric water heating.

$DRYER_{GAS, CORR}$ = Gas dryer correction factor; 1.12.¹³¹⁷

used as a proxy given consistency with the PJM peak definition; however, this value is likely conservatively low for commercial applications and is a candidate for update should more applicable data become available.

¹³¹⁶ Ibid.

¹³¹⁷ U.S. EPA. 2016. Savings Calculator for ENERGY STAR Qualified Appliances. Accessed March 7, 2016.

http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

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$DRYER_{GAS}$ = 1 if gas dryer; 0 if electric dryer.

Annual Water Savings Algorithm

$\Delta Water\ (CCF) = Capacity * (WF_{BASE} - WF_{EE}) * Ncycles / 748$

Where

- WF_{BASE} = Water Factor of baseline clothes washer.
= Values provided below.
- WF_{EE} = Water Factor of efficient clothes washer.
= Actual. If unknown assume value provided below.
- 748 = Conversion factor from gallons to CCF.

Efficiency Level	Water Factor (WF)	
	Front Loading	Top Loading
Federal Standard	On or After January 1, 2018	
	<= 4.1	<= 8.8
ENERGY STAR	<= 4.5	

KWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities’ must be careful not to double count the monetary benefit of these savings within cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

$$\Delta kWh_{\text{water}}^{1318} = 2.07 \text{ kWh/CCF} * \Delta \text{Water (CCF)}$$

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$200.¹³¹⁹

Measure Life

The measure life is assumed to be 7 years.¹³²⁰

Operation and Maintenance Impacts

n/a

¹³¹⁸ This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

¹³¹⁹ Energy Star calculator accessed April 25, 2017, which cites "Cadmus research in available models, 2016," which is based on Cadmus review in 2015 of 4 retailer websites - Sears, Home Depot, Lowes Best Buy.

¹³²⁰ Ibid

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Beverage and Snack Machine Controls

Unique Measure Code(s): CI AP VEND CONTROL

Effective Date: July 2024

End Date: TBD

Measure Description

This measure relates to the installation of new controls on refrigerated beverage vending machines, non-refrigerated snack vending machines, and glass front refrigerated coolers. Controls can significantly reduce the energy consumption of vending machine and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations. This measure relates to the installation of a new control on a new or existing unit. This measure should not be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

Vending machine categories are as defined¹³²¹ below:

- Refrigerated Beverage Vending Machine: A commercial refrigerator that cools bottled and/or canned beverages and dispenses the bottled and/or canned beverages on payment. Bottled or canned beverages means a beverage in a sealed container.
 - Class A Machine: A refrigerated bottled and/or canned beverage vending machine that is not a combination vending machine and in which 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.
 - Class B Machine: Any refrigerated bottled and/or canned beverage vending machine not considered to be Class A, and is not a combination

¹³²¹ Code of Federal Regulations at 10 CFR 431. Subpart Q §431.296.

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vending machine.

- Combination Vending Machine: A bottled and/or canned beverage vending machine containing two or more compartments separated by a solid partition, that may or may not share a product delivery chute, in which at least one compartment is designed to be refrigerated, as demonstrated by the presence of temperature controls, and at least one compartment is not.
 - Combination A: Combination vending machine where 25 percent or more of the surface area on the front side of the beverage vending machine is transparent.
 - Combination B: Combination vending machine that is not considered to be Combination A.

Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler without a control system capable of powering down lighting and refrigeration systems during periods of inactivity

Definition of Efficient Condition

The efficient equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler with a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

Annual Energy Savings Algorithm

$\Delta kWh = \Delta kWh_{lighting} + \Delta kWh_{RefBMC}$

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$$\Delta kWh_{\text{Lighting}} = (8760 - \text{OccHours}) * \text{WBulb} * (1/1000)$$

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$$\Delta kWh_{\text{RefBMC}} = \text{MDEC} * (\text{SleepHours} / 24) * \text{Days}$$

Where

OccHours = Average Annual Hours facility is occupied
= If Unknown, assume 3,379 hrs

WBulb = Wattage of bulb in refrigerated beverage vending machine
= If Unknown, use 56.4 W for fluorescent T8 lamps, and 31.6 W for TLEDs

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MDEC = Maximum Daily Energy Consumption per Federal regulations. Refrigerated Volume of 21 (ft3) used in the calculations. If unknown, assume Class B, post-2019

Class	Vintage	EQN	MDEC (kWh/d)
<u>A</u>	<u>post-2019</u>	<u>0.052 * V + 2.43</u>	<u>3.52</u>
<u>B</u>		<u>0.052 * V + 2.20</u>	<u>3.29</u>
<u>Combination A</u>		<u>0.086 * V + 2.66</u>	<u>4.47</u>
<u>Combination B</u>		<u>0.111 * V + 2.04</u>	<u>4.37</u>
<u>A</u>	<u>pre-2019</u>	<u>0.055 * V + 2.56</u>	<u>3.72</u>
<u>B</u>		<u>0.073 * V + 3.16</u>	<u>4.69</u>

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SleepHours = Maximum hours of sleep mode per day.

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Days = 365 Days

n/a

n/a

n/a

n/a

The measure life is assumed to be 5 years. ¹³²³

n/a

1323 Measure Life, Study, prepared for the Massachusetts Joint Utilities, Energy & Resource Solutions,
November, 2005

[illegible]

Plug Load End Use

Tier 1 Advanced Power Strip

Unique Measure Code: CI_PL_TOS_APS_0614

Effective Date: June 2014

End Date: TBD

Measure Description

This measure relates to the installation of a Current-Sensing Master/Controlled Advanced Power Strip (APS) in place of a standard “power strip,” a device used to expand a single wall outlet into multiple outlets. This measure is assumed to be a time of sale installation.

Definition of Baseline Condition

The baseline condition is a standard “power strip”. This strip is simply a “plug multiplier” that allows the user to plug in multiple devices using a single wall outlet. Additionally, the baseline unit has no ability to control power flow to the connected devices.

Definition of Efficient Condition

The efficient condition is a Current-Sensing Master/Controlled Advanced Power Strip that functions as both a “plug multiplier” and also as a plug load controller. The efficient unit has the ability to essentially disconnect controlled devices from wall power when the APS detects that a controlling device, or master load, has been switched off.

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The efficient device effectively eliminates standby power consumption for all controlled devices¹³²⁴ when the master load is not in use.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = 26.9 \text{ kWh}^{1325}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = 0 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

¹³²⁴ Most advanced power strips have one or more uncontrolled plugs that can be used for devices where a constant power connection is desired such as fax machines and wireless routers.

¹³²⁵ Energy & Resource Solutions. 2013. Emerging Technologies Research Report; Advanced Power Strips for Office Environments prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships.” Assumes savings consistent with the 20W threshold setting for the field research site (of two) demonstrating higher energy savings. ERS noted that the 20 W threshold may be unreliable due to possible inaccuracy of the threshold setting in currently available units. It is assumed that future technology improvements will reduce the significance of this issue. Further, savings from the site with higher average savings was adopted (26.9 kWh versus 4.7 kWh) acknowledging that investigations of APS savings in other jurisdictions have found significantly higher savings. For example, Northwest Power and Conservation Council, Regional Technical Forum. 2011. “Smart Power Strip Energy Savings Evaluation” found average savings of 145 kWh.

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Incremental Cost

The incremental cost for this time of sale measure is assumed to be \$18¹³²⁶.

Measure Life

The measure life is assumed to be 4 years.¹³²⁷

Operation and Maintenance Impacts

n/a

¹³²⁶ 2016 Illinois Technical Resource Manual

¹³²⁷ David Rogers, Power Smart Engineering, "Smart Strip Electrical Savings and Usability," October 2008.

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Tier 2 Advanced Power Strip

Unique Measure Code: CI PL TOS APS2

Effective Date: July 2024

End Date: TBD

Measure Description

This measure relates to the installation of a Current-Sensing Master/Controlled Advanced Power Strip (APS) with occupancy sensing capabilities in place of a standard “power strip,” a device used to expand a single wall outlet into multiple outlets.

Definition of Baseline Condition

The baseline condition is a standard “power strip”. This strip is simply a “plug multiplier” that allows the user to plug in multiple devices using a single wall outlet. Additionally, the baseline unit has no ability to control power flow to the connected devices.

Definition of Efficient Condition

The efficient condition is a Current-Sensing Master/Controlled Advanced Power Strip with occupancy sensing capabilities that functions as both a “plug multiplier” and also as a plug load controller. The efficient unit must have both the ability to essentially disconnect controlled devices from wall power when the APS detects that a controlling device, or master load, has been switched off, either via current-sensing or after a period of time the space is unoccupied.

The efficient device effectively eliminates standby power consumption for all controlled devices¹³²⁸ when the master load is not in use.

Annual Energy Savings Algorithm

$\Delta kWh = 185 kWh^{1329}$

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0 kW$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

n/a

Measure Life

The measure life is assumed to be 4 years.¹³³⁰

¹³²⁸ Most advanced power strips have one or more uncontrolled plugs that can be used for devices where a constant power connection is desired such as fax machines and wireless routers.

¹³²⁹ CA Statewide Workpaper - SWAP010-01 - 2022

¹³³⁰ David Rogers, Power Smart Engineering, "Smart Strip Electrical Savings and Usability," October 2008.

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Operation and Maintenance Impacts

n/a

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Commercial Kitchen Equipment End Use

Commercial Fryers

Unique Measure Code(s): CI_KE_TOS_FRY_0516

Effective Date: May 2016

End Date: TBD

Measure Description

Commercial fryers that have earned the ENERGY STAR offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Frypot insulation reduces standby losses resulting in a lower idle energy rate. This measure applies to both standard sized fryers and large vat fryers.¹³³¹ Standard sized fryers that have earned the ENERGY STAR are up to 30% more efficient than non-qualified models; large vat fryers are 35% more efficient. This measure applies to time of sale opportunities.

Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency electric fryer with a heavy load efficiency of 75% for standard sized equipment and 70% for large vat equipment or a gas fryer with heavy load efficiency of 35% for both standard sized and large vat equipment.

Definition of Efficient Condition

¹³³¹ Standard fryers measures >12 inches and < 18 inches wide, and have shortening capacities > 25 pounds and < 65 pounds. Large vat fryers measure > 18 inches and < 24 inches wide, and have shortening capacities > 50 pounds.

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The efficient equipment is assumed to be an ENERGY STAR qualified electric or gas fryer.¹³³²

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$

$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:¹³³³

i = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.

$kWh\_Cooking_i$ = daily cooking energy consumption (kWh).

kWh_Idle_i = daily idle energy consumption (kWh).

kWh_{base} = the annual energy usage of the baseline equipment calculated using baseline values.

¹³³² US EPA. December 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Version 3.0

¹³³³ Unless otherwise noted, all default assumptions are from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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<i>kWh_{eff}</i>	<i>= the annual energy usage of the efficient equipment calculated using efficient values.</i>
<i>HOURS_{DAY}</i>	<i>= average daily operating hours. = if average daily operating hours are unknown, assume default of 16 hours/day for standard fryers and 12 hours/day for large vat fryers.</i>
<i>E_{FOOD}</i>	<i>= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food = 0.167.</i>
<i>LB</i>	<i>= Pounds of food cooked per day (lb/day). = if average pounds of food cooked per day is unknown, assume default of 150 lbs/day.</i>
<i>DAYS</i>	<i>= annual days of operation. = if annual days of operation are unknown, assume default of 365 days.</i>
<i>EFF</i>	<i>= Heavy load cooking energy efficiency (%). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
<i>IDLE</i>	<i>= Idle energy rate (kW). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
<i>PC</i>	<i>= Production capacity (lb/hr). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>

Electric Fryer Performance Metrics: Baseline and Efficient Values

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Parameter	Standard Size		Large Vat	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
IDLE (kW)	1.05	0.80	1.35	1.10
EFF	75%	83%	70%	80%
PC	65	70	100	110

Summer Coincident Peak kW Savings Algorithm ¹³³⁴

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU_{Cooking_i} + MMBTU_{Idle_i}) \times DAYS$$

$$MMBTU_{Cooking_i} = LB \times E_{FOOD}/EFF_i$$

$$MMBTU_{Idle_i} = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

¹³³⁴ No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

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Where:¹³³⁵

$MMBTU_{Cooking_i}$ = daily cooking energy consumption (MMBTU).

$MMBTU_{Idle_i}$ = daily idle energy consumption (MMBTU).

$MMBTU_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values.

$MMBTU_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values.

E_{FOOD} = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food = 0.00057.

$IDLE$ = Idle energy rate (MMBTU/h).
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

Gas Fryer Performance Metrics: Baseline and Efficient Values

Parameter	Standard Size		Large Vat	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
IDLE (MMBTU/h)	0.014	0.009	0.016	0.012
EFF	35%	50%	35%	50%
PC	60	65	100	110

Annual Water Savings Algorithm

¹³³⁵ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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n/a

Incremental Cost¹³³⁶

For electric fryers, the incremental cost for this time of sale measure is assumed to be \$210 for standard sized equipment and \$0 for large vat equipment. For gas fryers, the incremental cost is assumed to be \$0 for standard sized equipment and \$1,120 for large vat equipment.

Measure Life

12 years¹³³⁷

Operation and Maintenance Impacts

n/a

¹³³⁶ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed April 25, 2017, which cites “EPA research using AutoQuotes, 2012.”
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>
¹³³⁷ US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Commercial Steam Cookers

Unique Measure Code(s): CI_KE_TOS_STMR_0615
Effective Date: June 2015
End Date: TBD

Measure Description

Energy efficient steam cookers that have earned the ENERGY STAR label offer shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery system. This measure applies to time of sale opportunities.

Definition of Baseline Condition

The baseline condition assumes a standard efficiency electric or gas boiler-style steam cooker.

Definition of Efficient Condition

The efficient condition assumes the installation of an ENERGY STAR qualified electric or gas steam cooker.¹³³⁸

Annual Energy Savings Algorithm

$$\begin{aligned} kWh_i &= (kWh_{Cooking_i} + kWh_{Idle_i}) \times DAYS \\ kWh_{Cooking_i} &= LB \times E_{FOOD} / EFF_i \\ kWh_{Idle_i} &= [(1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD} / EFF_i] \times TIME_{idle} \end{aligned}$$

¹³³⁸ US EPA. August 2003. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers Eligibility Criteria Version 1.2

$$\text{TIME}_{\text{idle}} = (\text{HOURS}_{\text{DAY}} - \text{LB}/(\text{PC}_i \times \text{PANS}))$$

$$\text{kWh}_i = [\text{LB} \times \text{E}_{\text{FOOD}}/\text{EFF}_i + ((1 - \text{PCT}_{\text{steam}}) \times \text{IDLE}_i + \text{PCT}_{\text{steam}} \times \text{PC}_i \times \text{PANS} \times \text{E}_{\text{FOOD}}/\text{EFF}_i) \times (\text{HOURS}_{\text{DAY}} - \text{LB}/(\text{PC}_i \times \text{PANS}))] \times \text{DAYS}$$

$$\Delta \text{kWh} = \text{kWh}_{\text{base}} - \text{kWh}_{\text{eff}}$$

Where:¹³³⁹

- i* = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.
- kWh_Cooking_i* = daily cooking energy consumption (kWh).
- kWh_Idle_i* = daily idle energy consumption (kWh).
- Time_{idle}* = daily idle time (h).
- kWh_{base}* = the annual energy usage of the baseline equipment calculated using baseline values.
- kWh_{eff}* = the annual energy usage of the efficient equipment calculated using efficient values.
- DAYS* = annual days of operation.
= if annual days of operation are unknown, assume default of 365 days.
- LB* = Pounds of food cooked per day (lb/day).

¹³³⁹ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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	<i>= if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.</i>
<i>E_{FOOD}</i>	<i>= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food</i> <i>= 0.0308.</i>
<i>EFF</i>	<i>= Heavy load cooking energy efficiency (%).</i> <i>= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
<i>PCT_{steam}</i>	<i>= percent of time in constant steam mode (%).</i> <i>= if percent of time in constant steam mode is unknown, assume default of 40%.</i>
<i>IDLE</i>	<i>= Idle energy rate (kW).</i> <i>= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
<i>PC</i>	<i>= Production capacity per pan (lb/hr).</i> <i>= default baseline production capacity per pan is 23.3. If actual efficient production capacity per pan is unknown, assume default of 16.7.</i>
<i>PANS</i>	<i>= number of pans per unit.</i> <i>= actual installed number of pans per unit.</i>
<i>HOURS_{DAY}</i>	<i>= average daily operating hours.</i> <i>= if average daily operating hours are unknown, assume default of 12 hours/day.</i>

Electric Steam Cooker Performance Metrics: Baseline and Efficient Values

Parameter	No. of Pans	Baseline Model		Energy Efficient Model
		Steam Generator	Boiler Based	All
IDLE (kW)	3	1.200	1.000	0.400
	4			0.530
	5			0.670
	6+			0.800
EFF	All	30%	26%	50%

Summer Coincident Peak kW Savings Algorithm ¹³⁴⁰

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU_{Cooking_i} + MMBTU_{Idle_i}) \times DAYS$$

$$MMBTU_{Cooking_i} = LB \times E_{FOOD}/EFF_i$$

$$MMBTU_{Idle_i} = [(1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD}/EFF_i] \times TIME_{Idle}$$

$$TIME_{Idle} = (HOURS_{DAY} - LB/(PC_i \times PANS))$$

¹³⁴⁰ No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

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$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + ((1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD}/EFF_i) \times (HOURS_{DAY} - LB/(PC_i \times PANS))] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

Where:¹³⁴¹

MMBTU_{base} = the annual energy usage of the baseline equipment calculated using baseline values.

MMBTU_{eff} = the annual energy usage of the efficient equipment calculated using efficient values.

MMBTU_{Cooking_i} = daily cooking energy consumption (MMBTU).

MMBTU_{Idle_i} = daily idle energy consumption (MMBTU).

E_{FOOD} = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food.
= 0.000105.

IDLE = Idle energy rate (MMBTU/h).
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

PC = Production capacity per pan (lb/hr).
= default baseline production capacity per pan is 23.3. If actual efficient production capacity per pan is unknown, assume default of 20.

Gas Steam Cooker Performance Metrics: Baseline and Efficient Values

¹³⁴¹ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Parameter	No. of Pans	Baseline Model		Energy Efficient Model
		Steam Generator	Boiler Based	All
IDLE (MMBTU)	3	0.018	0.015	0.00625
	4			0.00835
	5			0.01040
	6+			0.01250
EFF	All	18%	15%	38%

Annual Water Savings Algorithm

$$\Delta \text{Water} = (\text{GPH}_{\text{base}} - \text{GPH}_{\text{eff}}) \times \text{HOURS}_{\text{DAY}} \times \text{DAYS}.$$

Where:¹³⁴²

GPH_{base} = Water consumption rate (gal/h) of baseline equipment.
 = if water consumption rate of baseline equipment is unknown, assume default values from table below.

GPH_{eff} = Water consumption rate (gal/h) of efficient equipment.
 = if water consumption rate of efficient equipment is unknown, assume default values from table below.

¹³⁴² Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Parameter	No. of Pans	Baseline Model	Energy Efficient Model		
		All	Steam Generator	Boiler Based	Boilerless
GPH	All	40	15	10	3

Incremental Cost¹³⁴³

The incremental cost of a time of sale electric ENERGY STAR steam cooker is \$630 for 3-pans, \$1,210 for 4-pans, \$0 for 5-pans, and \$0 for 6-pans+. The incremental cost of a time of sale gas ENERGY STAR steam cooker is \$260 for 3-pans, N/A for 4-pans, \$0 for 5-pans, and \$870 for 6-pans+.

Measure Life

12 years¹³⁴⁴

Operation and Maintenance Impacts

n/a

¹³⁴³ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed April 25, 2017, which cites “EPA research using AutoQuotes, 2012.”
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

¹³⁴⁴ Ibid.

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Commercial Hot Food Holding Cabinets

Unique Measure Code(s): CI_KE_TOS_HFHC_0615
Effective Date: June 2015
End Date: TBD

Measure Description

Commercial insulated hot food holding cabinet models that meet ENERGY STAR requirements incorporate better insulation, reducing heat loss, and may also offer additional energy saving devices such as magnetic door gaskets, auto-door closures, or dutch doors. The insulation of the cabinet also offers better temperature uniformity within the cabinet from top to bottom. This means that qualified hot food holding cabinets are more efficient at maintaining food temperature while using less energy. This measure applies to time of sale opportunities.

Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency hot food holding cabinet.

Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified hot food holding cabinet.¹³⁴⁵

Annual Energy Savings Algorithm

$$\Delta kWh = (IDLE_{base} - IDLE_{eff}) / 1000 \times HOURS_{DAY} \times DAYS$$

¹³⁴⁵ US EPA. April 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0.

Where:¹³⁴⁶

$IDLE_{base}$

$1,000$

$HOURS_{DAY}$

$DAYS$

$=$ the idle energy rate of the baseline equipment (W). See table below for calculation of default values.

$=$ conversion of W to kW.

$=$ average daily operating hours.

$=$ annual days of operation.

$IDLE_{eff}$

$=$ the idle energy rate of the efficient equipment (W). If actual efficient values are unknown, assume default values from table below.

$=$ if average daily operating hours are unknown, assume default of 15 hours/day.

$=$ if annual days of operation are unknown, assume default of 365 days.

Summer Coincident Peak kW Savings Algorithm ¹³⁴⁷

$\Delta kW = (IDLE_{base} - IDLE_{eff}) / 1000$

Hot Food Holding Cabinet Performance Metrics: Baseline and Efficient Values	
VOLUME (Cubic Feet)	Product Idle Energy Consumption Rate (Watts)

¹³⁴⁶ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

¹³⁴⁷ No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

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	Baseline Model (IDLE _{base})	Efficient Model (IDLE _{eff})
0 < VOLUME < 13	40 x VOLUME	21.5 x VOLUME
13 ≤ VOLUME < 28	40 x VOLUME	2.0 x VOLUME + 254.0
28 ≤ VOLUME	40 x VOLUME	3.8 x VOLUME + 203.5

*Note: VOLUME = the internal volume of the holding cabinet (ft³).
= actual volume of installed unit*

Annual Fossil Fuel Savings Algorithm
n/a

Annual Water Savings Algorithm
n/a

Incremental Cost¹³⁴⁸
The incremental cost for a for this time of sale measure ENERGY STAR hot food holding cabinets is assumed to be \$0.

Measure Life
12 years¹³⁴⁹

¹³⁴⁸ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed April 25, 2017, which cites “EPA research using AutoQuotes, 2012.”
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

¹³⁴⁹ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

Operation and Maintenance Impacts
n/a

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Commercial Griddles

Unique Measure Code(s): CI_KE_TOS_GRID_0615
Effective Date: June 2015
End Date: TBD

Measure Description

ENERGY STAR qualified commercial griddles have higher cooking energy efficiency and lower idle energy rates than standard equipment. The result is more energy being absorbed by the food compared with the total energy use, and less wasted energy when the griddle is in standby mode. This measure applies to time of sale opportunities.

Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency electric griddle with a cooking energy efficiency of 65% or a gas griddle with a cooking efficiency of 32%.

Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified electric or gas griddle.¹³⁵⁰

Annual Energy Savings Algorithm

$$\begin{aligned} \text{kWh}_i &= (\text{kWh}_{\text{Cooking}_i} + \text{kWh}_{\text{Idle}_i}) \times \text{DAYS} \\ \text{kWh}_{\text{Cooking}_i} &= \text{LB} \times E_{\text{FOOD}} / \text{EFF}_i \\ \text{kWh}_{\text{Idle}_i} &= \text{IDLE}_i \times \text{SIZE} \times [\text{HOURS}_{\text{DAY}} - \text{LB} / (\text{PC}_i \times \text{SIZE})] \end{aligned}$$

¹³⁵⁰ US EPA. January 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles Eligibility Criteria Version 1.2.

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times SIZE \times (HOURS_{DAY} - LB/(PC_i \times SIZE))] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:¹³⁵¹

- i* = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.
- kWh_Cooking_i* = daily cooking energy consumption (kWh).
- kWh_Idle_i* = daily idle energy consumption (kWh).
- kWh_{base}* = the annual energy usage of the baseline equipment calculated using baseline values.
- kWh_{eff}* = the annual energy usage of the efficient equipment calculated using efficient values.
- LB* = Pounds of food cooked per day (lb/day) .
= if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.

¹³⁵¹ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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- E_{FOOD}

= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food.

= 0.139.
- EFF

= Heavy load cooking energy efficiency (%).

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
- $IDLE$

= Idle energy rate (kW/ft²).

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
- $SIZE$

= size of the griddle surface (ft²).
- $HOURS_{\text{DAY}}$

= average daily operating hours.

= if average daily operating hours are unknown, assume default of 12 hours/day.
- PC

= Production capacity (lb/hr/ft²).

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
- $DAYS$

= annual days of operation.

= if annual days of operation are unknown, assume default of 365 days.

Efficient Griddle Performance Metrics: Baseline and Efficient Values		
Parameter	Baseline Model	Efficient Model
IDLE (kW/ft ²)	0.40	0.32
EFF	65%	70%
PC	5.83	6.67

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Summer Coincident Peak kW Savings Algorithm¹³⁵²

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU_{Cooking_i} + MMBTU_{Idle_i}) \times DAYS$$

$$MMBTU_{Cooking_i} = LB \times E_{FOOD} / EFF_i$$

$$MMBTU_{Idle_i} = IDLE_i \times SIZE \times [HOURS_{DAY} - LB / (PC_i \times SIZE)]$$

$$MMBTU_i = [LB \times E_{FOOD} / EFF_i + IDLE_i \times SIZE \times (HOURS_{DAY} - LB / (PC_i \times SIZE))] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

Where:¹³⁵³

MMBTU_{Cooking_i} = daily cooking energy consumption (MMBTU).

MMBTU_{Idle_i} = daily idle energy consumption (MMBTU).

¹³⁵² No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

¹³⁵³ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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MMBTU_{base} = the annual energy usage of the baseline equipment calculated using baseline values.

MMBTU_{eff} = the annual energy usage of the efficient equipment calculated using efficient values.

E_{FOOD} = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food.
= 0.000475.

IDLE = Idle energy rate (MMBTU/h/ft²).
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

Gas Griddle Performance Metrics: Baseline and Efficient Values

Parameter	Baseline Model	Efficient Model
IDLE (MMBTU/h/ft ²)	0.00350	0.00265
EFF	32%	38%
PC	4.17	7.50

Annual Water Savings Algorithm

n/a

Incremental Cost¹³⁵⁴

¹³⁵⁴ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed April 25, 2017, which cites “EPA research using AutoQuotes, 2012.”
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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The incremental cost of a time of sale electric ENERGY STAR griddle is assumed to be \$0. The incremental cost of a time of sale gas ENERGY STAR griddle is assumed to be \$360.

Measure Life

12 years¹³⁵⁵

Operation and Maintenance Impacts

n/a

¹³⁵⁵ Ibid.

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Commercial Convection Ovens

Unique Measure Code(s): CI_KE_TOS_CONOV_0619
Effective Date: June 2019
End Date: TBD

Measure Description

Commercial convection ovens that are ENERGY STAR certified have higher heavy load cooking efficiencies and lower idle energy rates making them on average about 20 percent more efficient than standard models. This measure applies to time of sale opportunities.

Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency convection oven with a heavy load efficiency of 65% for full size (i.e., a convection oven this is capable of accommodating full-size sheet pans measuring 18 x 26 x 1-inch) electric ovens, 68% for half size (i.e., a convection oven that is capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch) electric ovens, and 30% for gas ovens.

Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR Version 2.2 qualified electric or gas convection oven.¹³⁵⁶

Annual Energy Savings Algorithm

$$kWh_i = (kWh_{Cooking_i} + kWh_{Idle_i}) \times DAYS$$

¹³⁵⁶ US EPA. October 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2

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$$\begin{aligned} kWh\_Cooking_i &= LB \times E_{FOOD}/EFF_i \\ kWh\_Idle_i &= IDLE_i \times (HOURS_{DAY} - LB/PC_i) \\ kWh_i &= [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS \\ \Delta kWh &= kWh_{base} - kWh_{eff} \end{aligned}$$

Where:¹³⁵⁷

- i* = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.
- kWh_Cooking_i* = daily cooking energy consumption (kWh).
- kWh_Idle_i* = daily idle energy consumption (kWh).
- kWh_{base}* = the annual energy usage of the baseline equipment calculated using baseline values.
- kWh_{eff}* = the annual energy usage of the efficient equipment calculated using efficient values.
- HOURS_{DAY}* = average daily operating hours.

¹³⁵⁷ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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- DAYS

= if average daily operating hours are unknown, use default values from Oven Operation by Building Type below

= annual days of operation.

= if annual days of operation are unknown, use default values from Oven Operation by Building Type below
- E_{FOOD}

= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food

= 0.0732.
- LB

= Pounds of food cooked per day (lb/day).

= if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.
- EFF

= Heavy load cooking energy efficiency (%).

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
- IDLE

= Idle energy rate (kW).

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
- PC

= Production capacity (lb/hr).

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

Oven Operation by Building Type ¹³⁵⁸		
Facility Type	hours/day	days/year
Community College	11	283
Fast Food Restaurant	14	363
Full Service Restaurant	12	321

¹³⁵⁸ California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

Grocery	12	365
Hospital	11	365
Hotel	20	365
Miscellaneous	9	325
Motel	20	365
Primary School	5	180
Secondary School	8	180
Office	12	250
University	11	283

Electric Convection Oven Performance Metrics: Baseline and Efficient Values¹³⁵⁹

Parameter	Half Size		Full Size	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
IDLE (kW)	1.03	1.00	2.00	1.60
EFF	68%	71%	65%	71%
PC	45	50	90	90

Summer Coincident Peak kW Savings Algorithm¹³⁶⁰

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

¹³⁵⁹ Food Service Technology Center (FSTC). Default value from life cycle cost calculator. <http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php>.

¹³⁶⁰ No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

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$$\text{MMBTU}_i = (\text{MMBTU\_Cooking}_i + \text{MMBTU\_Idle}_i) \times \text{DAYS}$$

$$\text{MMBTU\_Cooking}_i = \text{LB} \times E_{\text{FOOD}} / \text{EFF}_i$$

$$\text{MMBTU\_Idle}_i = \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB}/\text{PC}_i)$$

$$\text{MMBTU}_i = [\text{LB} \times E_{\text{FOOD}} / \text{EFF}_i + \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB}/\text{PC}_i)] \times \text{DAYS}$$

$$\Delta \text{MMBTU} = \text{MMBTU}_{\text{base}} - \text{MMBTU}_{\text{eff}}$$

Where:¹³⁶¹

MMBTU_Cooking_i = daily cooking energy consumption (MMBTU).

MMBTU_Idle_i = daily idle energy consumption (MMBTU).

MMBTU_{base} = the annual energy usage of the baseline equipment calculated using baseline values.

MMBTU_{eff} = the annual energy usage of the efficient equipment calculated using efficient values.

E_{FOOD} = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food.
= 0.000250.

IDLE = Idle energy rate (MMBTU/h).
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

¹³⁶¹ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

Gas Convection Oven Performance Metrics: Baseline and Efficient Values

Parameter	Baseline Model	Energy Efficient Model
IDLE (MMBTU/h)	0.0151	0.0120
EFF	44%	46%
PC	83	86

Annual Water Savings Algorithm

n/a

Incremental CostThe incremental cost for this time of sale measure is assumed to be \$0.¹³⁶²**Measure Life**12 years¹³⁶³**Operation and Maintenance Impacts**

n/a

¹³⁶² Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed April 25, 2017, which cites “EPA research using AutoQuotes, 2013.”
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

¹³⁶³ US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Commercial Combination Ovens

Unique Measure Code(s): CI_KE_TOS_COMOV_0619
Effective Date: June 2019
End Date: TBD

Measure Description

A combination oven is a convection oven that includes the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes. This measure applies to time of sale opportunities.

Definition of Baseline Condition

The baseline equipment is assumed to be a typical standard efficiency electric or gas combination oven.

Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR Version 2.2 qualified electric or gas combination oven.¹³⁶⁴

Annual Energy Savings Algorithm

$$\begin{aligned} kWh_{i,j} &= (kWh_{Cooking_{i,j}} + kWh_{Idle_{i,j}}) \times DAYS \\ kWh_{Cooking_{i,j}} &= LB \times E_{FOOD,j} / EFF_{i,j} \times PCT_j \\ kWh_{Idle_{i,j}} &= IDLE_{i,j} \times (HOURS_{DAY} - LB / PC_{i,j}) \times PCT_j \end{aligned}$$

¹³⁶⁴ US EPA. October 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2

$$kWh_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$kWh_{base} = kWh_{base,conv} + kWh_{base,steam}$$

$$kWh_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:¹³⁶⁵

i = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.

j = cooking mode; either “conv” (i.e., convection) or “steam”.

kWh_Cooking_{i,j} = daily cooking energy consumption (kWh).

kWh_Idle_{i,j} = daily idle energy consumption (kWh).

kWh_{base} = the annual energy usage of the baseline equipment calculated using baseline values.

kWh_{eff} = the annual energy usage of the efficient equipment calculated using efficient values.

HOURS_{DAY} = average daily operating hours.

¹³⁶⁵ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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	<i>= if average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in “Commercial Convection Ovens”</i>
DAYS	<i>= annual days of operation. = if annual days of operation are unknown, refer to the default values from Oven Operation by Building Type in “Commercial Convection Ovens”.</i>
$E_{FOOD,conv}$	<i>= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during convention mode cooking, per pound of food. = 0.0732.</i>
$E_{FOOD,steam}$	<i>= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during steam mode cooking, per pound of food. = 0.0308.</i>
LB	<i>= Pounds of food cooked per day (lb/day). = if average pounds of food cooked per day is unknown, assume default of 200 lbs/day.</i>
EFF	<i>= Heavy load cooking energy efficiency (%). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
IDLE	<i>= Idle energy rate (kW). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
PC	<i>= Production capacity (lb/hr). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.</i>
PCT_j	<i>= percent of food cooked in cooking mode j. Note: $PCT_{conv} + PCT_{steam}$ must equal 100%.</i>

= if percent of food cooked in cooking mode j is unknown, assume default of $PCT_{conv} = PCT_{steam} = 50\%$.

Electric Combination Oven Performance Metrics: Baseline and Efficient Values

Parameter	No. of Pans	Baseline Model		Energy Efficient Model	
		Convection Mode	Steam Mode	Convection Mode	Steam Mode
IDLE (kW)	< 15	1.320	5.260	0.08 x PANS +	0.133 x PANS
	>= 15	2.280	8.710	0.4989	+ 0.64
EFF	All	72%	49%	76%	55%
PC	< 15	79	126	119	177
	>= 15	166	295	201	349

Note: PANS = The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.

Summer Coincident Peak kW Savings Algorithm ¹³⁶⁶

$$\Delta kW = \Delta kWh / (\text{HOURS}_{\text{DAY}} \times \text{DAYS})$$

Annual Fossil Fuel Savings

$$\text{MMBTU}_i = [\text{LB} \times E_{\text{FOOD}}/\text{EFF}_i + \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB}/\text{PC}_i)] \times \text{DAYS}$$

$$\text{MMBTU}_{\text{Cooking}_{i,j}} = \text{LB} \times E_{\text{FOOD},j}/\text{EFF}_{i,j} \times \text{PCT}_j$$

¹³⁶⁶ No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

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$$\text{MMBTU\_Idle}_{i,j} = \text{IDLE}_{i,j} \times (\text{HOURS}_{\text{DAY}} - \text{LB}/\text{PC}_{i,j}) \times \text{PCT}_j$$

$$\text{MMBTU}_{i,j} = [\text{LB} \times E_{\text{FOOD},j}/\text{EFF}_{i,j} + \text{IDLE}_{i,j} \times (\text{HOURS}_{\text{DAY}} - \text{LB}/\text{PC}_{i,j})] \times \text{PCT}_j \times \text{DAYS}$$

$$\text{MMBTU}_{\text{base}} = \text{kWh}_{\text{base,conv}} + \text{kWh}_{\text{base,steam}}$$

$$\text{MMBTU}_{\text{eff}} = \text{kWh}_{\text{eff,conv}} + \text{kWh}_{\text{eff,steam}}$$

$$\Delta \text{MMBTU} = \text{MMBTU}_{\text{base}} - \text{MMBTU}_{\text{eff}}$$

Where:¹³⁶⁷

MMBTU_Cooking_i = daily cooking energy consumption (MMBTU).

MMBTU_Idle_i = daily idle energy consumption (MMBTU).

MMBTU_{base} = the annual energy usage of the baseline equipment calculated using baseline values.

MMBTU_{eff} = the annual energy usage of the efficient equipment calculated using efficient values.

E_{FOOD,conv} = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during convention mode cooking, per pound of food.

= 0.000250.

E_{FOOD,steam} = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during steam mode cooking, per pound of food.

¹³⁶⁷ Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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LB

IDLE

Parameter	No. of Pans	Baseline Model		Energy Efficient Model	
		Convection Mode	Steam Mode	Convection Mode	Steam Mode
IDLE (MMBTU/h)	< 15	0.008747	0.018656	0.000150 x PANS + 0.005425	0.000200 x PANS + 0.006511
	>= 15 and < 30	0.007823	0.024562		
	>= 30	0.013000	0.043300		
EFF	All	52%	39%	56%	41%
PC	< 15	125	195	124	172
	>= 15 and < 30	176	211	210	277
	>= 30	392	579	394	640

Annual Water Savings Algorithm

Incremental Cost

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The incremental cost for this time of sale measure commercial combination ovens is assumed to be \$0.¹³⁶⁸

Measure Life

12 years¹³⁶⁹

Operation and Maintenance Impacts

n/a

¹³⁶⁸ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed April 25, 2017, which cites “EPA research using AutoQuotes, 2013.”
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

¹³⁶⁹ Ibid.

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ENERGY STAR Commercial Rack Oven

Unique Measure Code(s): CI_KE_TOS_RACKOV_0619
Effective Date: June 2019
End Date: TBD

Measure Description

This measure describes a time of sale or new construction installation of an ENERGY STAR qualified, single or double gas rack oven. These large commercial ovens are frequently used in high volume backing facilities and other food service operations, such as supermarkets, high volume bakeries, and institutions.

Definition of Baseline Condition

The baseline condition is a standard efficiency gas rack oven.

Definition of Efficient Condition

The efficient condition is a high-efficiency gas rack oven meeting ENERGY STAR Version 2.2 requirements¹³⁷⁰.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

¹³⁷⁰ ENERGY STAR Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2, ENERGY STAR, October 2015.

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$$\Delta \text{MMBTU} = \text{DAYS} * (\Delta \text{BTU}_{\text{preheat}} + \Delta \text{BTU}_{\text{idle}} + \Delta \text{BTU}_{\text{cooking}}) / 1,000,000$$

$$\Delta \text{BTU}_{\text{preheat}} = N_{\text{preheat}} * (\text{BTU}_{\text{preheat,baseline}} - \text{BTU}_{\text{preheat,ee}})$$

$$\Delta \text{BTU}_{\text{idle}} = (\text{BTU}/\text{h}_{\text{idle,baseline}} - \text{BTU}/\text{h}_{\text{idle,ee}}) * (\text{HOURS}_{\text{day}} - N_{\text{preheat}} * \text{hrs}_{\text{preheat}} - (\text{LB} / \text{PC}))$$

$$\Delta \text{BTU}_{\text{cooking}} = \text{LB} * E_{\text{food}} * (1/\text{Eff}_{\text{baseline}} - 1/\text{Eff}_{\text{ee}})$$

Where:

DAYS = annual days of operation.
= If annual days of operation are unknown, refer to the default values from Oven Operation by Building Type in “Commercial Convection Ovens”.

HOURS_{day} = average daily operating hours.
= If average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in “Commercial Convection Ovens”.

N_{preheat} = Number of preheats per day. If unknown use 1¹³⁷¹ preheat per day.

hrs_{preheat} = Preheat duration (hrs). Assume 0.33¹³⁷² if unknown.

BTU_{preheat,base} = Equipment preheat energy (BTU). Use default values in Default Assumptions for Rack Ovens below.

¹³⁷¹ PG&E Work Paper PGECOFST109 Revision 5, Table 12, pg. 7, Download from <http://deeresources.net/workpapers>

¹³⁷² Ibid.

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- $BTU_{preheat,ee}$

= Equipment preheat energy (BTU). Use default values in Default Assumptions for Rack Ovens below if unknown.
- $BTU/h_{idle,base}$

= Equipment idle energy rate (BTU/h). Use default values in Default Assumptions for Rack Ovens table below.
- $BTU/h_{idle,ee}$

= Equipment idle energy rate (BTU/h). Use default values in Default Assumptions for Rack Ovens table below if unknown.
- LB

= Pounds of food cooked per day (lb/day). Use default values in Default Assumptions for Rack Ovens table below if unknown.
- PC

= Production capacity (lb/hr). Use default values in Default Assumptions for Rack Ovens table below if unknown.
- E_{food}

= ASTM Energy to Food (Btu/lb); the amount of energy absorbed by the food during cooking, per pound of food. Assume 235¹³⁷³ if unknown.
- Eff_{base}

= Equipment convection/steam mode cooking efficiency (%). Use 30%¹³⁷⁴ if unknown.
- Eff_{base}

= Equipment convection/steam mode cooking efficiency (%). Use default values for Eff_{ee} in Oven Operation by Building Type table below if unknown.

Default Assumptions for Rack Ovens¹³⁷⁵

Variable	Rack Oven, Gas, Double Rack	Rack Oven, Gas, Single Rack
LB	1,200	600
$BTU_{preheat,baseline}$	100,000	50,000

¹³⁷³ Ibid.

¹³⁷⁴ Ibid.

BTU _{preheat,ee}	85,000	44,000
BTU/h _{idle,baseline}	65,000	43,000
BTU/h _{idle,ee}	30,000	25,000
PC	250	130
Eff _{ee}	52%	48%

Annual Water Savings Algorithm

n/a

Incremental CostThe incremental cost for this time of sale measure is assumed to be \$4,128¹³⁷⁶**Measure Life**12 years¹³⁷⁷**Operation and Maintenance Impacts**

n/a

¹³⁷⁶ PG&E Work Paper PGECOFST109 Revision 5, At-a-Glance Summary, page ii - Download from <http://deeresources.net/workpapers>

¹³⁷⁷ Food Service Technology Center: Gas Rack Oven Life-Cycle Cost Calculator, <https://caenergywise.com/calculators/natural-gas-rack-ovens/#calc>

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Commercial Conveyor Oven

Unique Measure Code(s): CI_KE_TOS_RACKOV_0619
Effective Date: June 2019
End Date: TBD

Measure Description

This measure describes a time of sale or new construction installation of a high-efficiency gas-fired conveyor oven. Conveyor ovens are used in the large-scale production of various food service operations and are used extensively for pizza production.

Definition of Baseline Condition

The baseline condition is a standard efficiency gas conveyor with an efficiency of 20%, a preheat energy of 35,000, an idle energy rate of 70,000 BTU/h, and a production capacity (PC) of 114 lbs/hr.

Definition of Efficient Condition

The efficient condition is a high-efficiency gas rack oven meeting minimum requirements of qualified conveyor ovens by the Food Service Technology Center (FSTC). Minimum requirements are shown below, in “Minimum Conveyor Oven Requirements”.

Minimum Conveyor Oven Requirements	
BTU _{preheat}	18,000
BTU/h _{idle}	57,000
Eff	42%
PC	167

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Annual Energy Savings Algorithm
n/a

Summer Coincident Peak kW Savings Algorithm
n/a

Annual Fossil Fuel Savings Algorithm

$$\begin{aligned}\Delta\text{MMBTU} &= \text{DAYS} * (\Delta\text{BTU}_{\text{preheat}} + \Delta\text{BTU}_{\text{idle}} + \Delta\text{BTU}_{\text{cooking}}) / 1,000,000 \\ \Delta\text{BTU}_{\text{preheat}} &= N_{\text{preheat}} * (\text{BTU}_{\text{preheat,baseline}} - \text{BTU}_{\text{preheat,ee}}) \\ \Delta\text{BTU}_{\text{idle}} &= (\text{BTU}/\text{h}_{\text{idle,baseline}} - \text{BTU}/\text{h}_{\text{idle,ee}}) * (\text{HOURS}_{\text{day}} - N_{\text{preheat}} * \text{hrs}_{\text{preheat}} - (\text{LB} / \text{PC})) \\ \Delta\text{BTU}_{\text{cooking}} &= \text{LB} * E_{\text{food}} * (1/\text{Eff}_{\text{baseline}} - 1/\text{Eff}_{\text{ee}})\end{aligned}$$

Where:

DAYS = annual days of operation. If unknown, refer to the default values from Oven Operation by Building Type found in the “Commercial Convection Oven” measure.

HOURS_{day} = average daily operating hours.
= If average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in the “Commercial Convection Oven” measure .

$N_{preheat}$	= Number of preheats per day. If unknown use 1 ¹³⁷⁸ preheat per day.
$hrs_{preheat}$	= Preheat duration (hrs). Assume 0.25 ¹³⁷⁹ if unknown.
$BTU_{preheat,base}$	= Equipment preheat energy (BTU). Use 35,000 ¹³⁸⁰ by default.
$BTU_{preheat,ee}$	= Actual equipment preheat energy (BTU).
$BTU/h_{idle,base}$	= Equipment idle energy rate (BTU/h). Use 70,000 ¹³⁸¹ by default.
$BTU/h_{idle,ee}$	= Actual equipment idle energy rate (BTU/hr).
LB	= Pounds of food cooked per day (lb/day). Use 190 ¹³⁸² if unknown.
$PC_{baseline}$	= Production capacity (lb/hr). Use 114 ¹³⁸³ if unknown.
PC_{ee}	= Actual production capacity (lb/hr)..
E_{food}	= ASTM Energy to Food (Btu/lb); the amount of energy absorbed by the food during cooking, per pound of food. Assume 250 ¹³⁸⁴ if unknown.
$Eff_{baseline}$	= Equipment convection/steam mode cooking efficiency (%). Use 20% ¹³⁸⁵ if unknown.

¹³⁷⁸ PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, Download from <http://deeresources.net/workpapers>

¹³⁷⁹ PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6 - Download from <http://deeresources.net/workpapers>

¹³⁸⁰ Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, <https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc>

¹³⁸¹ Ibid.

¹³⁸² PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, where 1 pizza equals 0.76 lbs - Download from <http://deeresources.net/workpapers>

¹³⁸³ Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, where 1 pizza equals 0.76 lbs, <https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc>

¹³⁸⁴ PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, where 1 pizza equals 0.76 lbs - Download from <http://deeresources.net/workpapers>

¹³⁸⁵ Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, <https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc>

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Eff_{ee} = Actual equipment convection/steam mode cooking efficiency (%).

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure is assumed to be \$2,230¹³⁸⁶.

Measure Life

12 years¹³⁸⁷

Operation and Maintenance Impacts

n/a

¹³⁸⁶ PG&E Work Paper PGECOFST117 Revision 5, At-a-Glance Summary, pg. ii - Download from <http://deeresources.net/workpapers>

¹³⁸⁷ Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, <https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc>

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Air-Cooled Commercial Ice Makers

Unique Measure Code(s): CI_KE_TOS_ICE_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency, air-cooled automatic commercial ice maker which are used in restaurants, bars, hotels, hospitals and a variety of commercial and industrial facilities for both food and patient care applications.

Definition of Baseline Condition

The baseline condition is a standard-efficiency automatic, air-cooled commercial ice maker meeting, but not exceeding, federal energy efficiency standards.

Definition of Efficient Condition

The efficient condition is a high-efficiency automatic commercial ice maker meeting ENERGY STAR Version 3.0 requirements.¹³⁸⁸

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = (\text{ECR}_{\text{base}} - \text{ECR}_{\text{EE}}) / 100 \times \text{DAYS} \times \text{DUTY} \times \text{H}$$

¹³⁸⁸ ENERGY STAR® Program Requirements For Automatic Commercial Ice Makers Partner Commitments, https://www.energystar.gov/sites/default/files/Final%20V3.0%20ACIM%20Specification%205-17-17_1_0.pdf

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Where:

- ECR_{base}

= the energy consumption rate of the baseline (kWh/100 lb ice). This value is calculated from the tables below using ice harvest rate.
- ECR_{EE}

= the energy consumption rate of the efficient equipment (kWh/100 lb ice). This value is calculated from the tables below using ice harvest rate.
- DAYS

= annual days of operation.
= if annual days of operation are unknown, assume default of 365 days.
- DUTY

= duty cycle of ice maker.
= 0.40¹³⁸⁹
- H

= harvest rate (lb ice/24 hours) of the efficient equipment.

Batch Type Commercial Ice Makers			
Equipment type	Harvest rate (lb ice/24 hours)	Federal Baseline Maximum Energy Consumption Rate (kWh/100 lb ice) ¹³⁹⁰	ENERGY STAR Maximum Energy Consumption Rate (kWh/100 lb ice) ¹³⁹¹
Ice-Making Head	< 300	10-0.01233*H	9.20 - 0.01134*H

¹³⁹⁰ CFR Title 10 → Chapter II → Subchapter D → §431.136
<https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53>

¹³⁹¹
https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

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Ice-Making Head	≥ 300 and < 800	7.05-0.0025*H	6.49 - 0.0023*H
Ice-Making Head	≥ 800 and < 1,500	5.55-0.00063*H	5.11 - 0.00058*H
Ice-Making Head	≥ 1,500 and < 4,000	4.61	4.24
Remote Condensing (but not remote compressor)	< 988	7.97-0.00342*H	7.17 – 0.00308*H
Remote Condensing (but not remote compressor)	≥ 988 and < 4,000	4.59	4.13
Remote Condensing and Remote Compressor	< 930	7.97-0.00342*H	7.17 – 0.00308*H
Remote Condensing and Remote Compressor	≥ 930 and < 4,000	4.79	4.13
Self-Contained	< 110	14.79-0.0469*H	12.57 - 0.0399*H
Self-Contained	≥ 110 and < 200	12.42-0.02533*H	10.56 – 0.0215*H
Self-Contained	≥ 200 and < 4,000	7.35	6.25

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https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

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Continuous Type Commercial Ice Makers			
Equipment type	Harvest rate (lb ice/24 hours)	Federal Baseline Maximum Energy Consumption Rate (kWh/100 lb ice) ¹³⁹²	ENERGY STAR Maximum Energy Consumption Rate (kWh/100 lb ice) ¹³⁹³
Ice-Making Head	<310	9.19-0.00629*H	7.90 – 0.005409*H
Ice-Making Head	≥310 and <820	8.23-0.0032*H	7.08 – 0.002752*H
Ice-Making Head	≥820 and <4,000	5.61	4.82
Remote Condensing (but not remote compressor)	<800	9.7-0.0058*H	7.76 – 0.00464*H
Remote Condensing (but not remote compressor)	≥800 and <4,000	5.06	4.05
Remote Condensing and Remote Compressor	<800	9.9-0.0058*H	7.76 – 0.00464*H

¹³⁹²

CFR Title 10 → Chapter II → Subchapter D → §431.136

https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53¹³⁹³https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

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Remote Condensing and Remote Compressor	≥800 and <4,000	5.26	4.05
Self-Contained	<200	14.22-0.03*H	12.37 – 0.0261*H
Self-Contained	≥200 and <700	9.47-0.00624*H	8.24 – 0.005429*H
Self-Contained	≥700 and <4,000	5.1	4.44

Summer Coincident Peak kW Savings Algorithm ¹³⁹⁴

$$\Delta kW = (ECR_{base} - ECR_{EE}) / 2,400 \times H \times CF$$

Where:

$$CF = \text{Summer Peak Coincident Factor for measure} \\ = 0.772^{1395}$$

Annual Fossil Fuel Savings Algorithm

n/a

¹³⁹⁴ No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

¹³⁹⁵ Assumes that the summer peak coincidence factor for commercial ice machines is consistent with that of general commercial refrigeration equipment. Characterization assumes a value of 77.2% adopted from the Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, March, 16, 2015, until a region specific study is conducted.

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Water Savings Algorithm¹³⁹⁶

The water savings associated with this measure vary depending on the configuration of the ice machine and are listed in the table below.

Ice Maker Type	Annual Water Savings (gal/unit)
Ice Making Head	3,322
Self-Contained Unit	3,526
Remote Condensing Unit (Batch)	2,631
Remote Condensing Unit (Continuous)	0

Incremental Cost¹³⁹⁷

The incremental cost for this time of sale measure ENERGY STAR commercial ice maker is assumed to be \$0.

Measure Life

¹³⁹⁶ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

¹³⁹⁷ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment accessed February 29, 2019, which cites “EPA research using AutoQuotes, 2012.” <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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8 years¹³⁹⁸

Operation and Maintenance Impacts
n/a

¹³⁹⁸ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Commercial Dishwashers

Unique Measure Code(s): CI_KE_TOS_DISH_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency stationary and conveyor-type commercial dishwashers used in commercial kitchen establishments that use non-disposable dishes, glassware, and utensils. Commercial dishwashers can clean and sanitize a large quantity of kitchenware in a short amount of time by utilizing hot water, soap, rinse chemicals, and significant amounts of energy. Energy Star qualified models use less water and have lower idling rates than non-Energy Star rated models.

This measure is not applicable to flight machines, which are continuous conveyor machines built specifically for large institutions.

Definition of Baseline Condition

The baseline condition is a standard non-ENERGY STAR commercial dishwasher.¹³⁹⁹

Definition of Efficient Condition

¹³⁹⁹ The baseline condition is based on the assumptions used for the conventional commercial dishwashers in the ENERGY STAR Savings Calculator for Certified Commercial Kitchen Equipment.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.

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The efficient condition is a high-efficiency commercial dishwasher meeting ENERGY STAR Version 2.0 requirements.¹⁴⁰⁰

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{Base} - kWh_{EFF}$

Where:

- kWh_{BASE} = Baseline kWh consumption per year
= Values provided in tables below.
- kWh_{EFF} = ENERGY STAR kWh consumption per year
= Values provided in tables below.

Commercial Dishwasher Annual Energy Use (kWh) ¹⁴⁰¹				
Building hot water fuel type / Booster water heater fuel type	Electric / Electric		Electric / Natural Gas	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
Low Temperature				
Under Counter	9,403	7,225	9,403	7,225
Stationary Single Tank Door	33,683	19,832	33,683	19,832
Single Tank Conveyor	36,189	24,504	36,189	24,504

¹⁴⁰⁰ ENERGY STAR Program Requirements for Commercial Dishwashers Version 2.0, ENERGY STAR, February 2013.
¹⁴⁰¹ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Multi Tank Conveyor	42,943	26,812	42,943	26,812
High Temperature				
Under Counter	10,595	7,876	8,083	5,894
Stationary Single Tank Door	34,151	23,978	23,053	16,321
Single Tank Conveyor	39,070	31,171	28,378	22,568
Multi Tank Conveyor	62,148	38,645	44,265	28,690
Pot, Pan, and Utensil	18,064	15,225	12,041	10,235

Commercial Dishwasher Annual Energy Use (kWh) ¹⁴⁰²				
Building hot water fuel type / Booster water heater fuel type	Natural Gas / Natural Gas		Natural Gas / Electric	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
Low Temperature				
Under Counter	2,426	2,426	2,426	2,426
Stationary Single Tank Door	2,066	2,066	2,066	2,066
Single Tank Conveyor	8,013	7,512	8,013	7,512
Multi Tank Conveyor	9,390	9,390	9,390	9,390
High Temperature				
Under Counter	3,687	2,426	6,199	4,408
Stationary Single Tank Door	3,631	2,921	14,729	10,578
Single Tank Conveyor	9,665	7,512	20,358	16,115
Multi Tank Conveyor	12,971	11,268	30,853	21,223
Pot, Pan, and Utensil	1,502	1,502	7,525	6,492

¹⁴⁰² Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh \times CF / HOURS$

Where:

- HOURS = annual operating hours.*
=5,634¹⁴⁰³
- CF = Summer Peak Coincident Factor for measure*
= 0.9¹⁴⁰⁴

Annual Fossil Fuel Savings Algorithm

$\Delta MMBtu = MMBtu_{BASE} - MMBtu_{EFF}$

Where:

- MMBtu_{BASE} = Baseline natural gas consumption per year*
= Values provided in tables below.
- MMBtu_{EFF} = ENERGY STAR natural gas consumption per year*
= Values provided in tables below.

Commercial Dishwasher Annual Energy Use (MMBtu) ¹⁴⁰⁵

¹⁴⁰³ The ENERGY STAR default value of 365 days per year seems excessive. 6 day operation is assumed (365 * 6/7) = 313 days/year at 18 hours per day, or 5,634 hours per year. This approach aligns with the MA TRM.

¹⁴⁰⁴ PG&E Work Paper PGECOFST126 Revision 0, Table 10, pg. 18

¹⁴⁰⁵ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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<i>Building hot water fuel type / Booster water heater fuel type</i>	Electric / Electric		Electric / Natural Gas	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
Low Temperature				
Under Counter	0.0	0.0	0.0	0.0
Stationary Single Tank Door	0.0	0.0	0.0	0.0
Single Tank Conveyor	0.0	0.0	0.0	0.0
Multi Tank Conveyor	0.0	0.0	0.0	0.0
High Temperature				
Under Counter	0.0	0.0	10.5	8.3
Stationary Single Tank Door	0.0	0.0	46.4	32.0
Single Tank Conveyor	0.0	0.0	44.7	36.0
Multi Tank Conveyor	0.0	0.0	74.8	41.6
Pot, Pan, and Utensil	0.0	0.0	25.2	20.9

Commercial Dishwasher Annual Energy Use (MMBtu) ¹⁴⁰⁶				
<i>Building hot water fuel type / Booster water heater fuel type</i>	Natural Gas / Natural Gas		Natural Gas / Electric	
	Baseline	ENERGY STAR	Baseline	ENERGY STAR
Low Temperature				
Under Counter	29.2	20.1	29.2	20.1
Stationary Single Tank Door	132.2	74.3	132.2	74.3

¹⁴⁰⁶ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation.
http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx

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Single Tank Conveyor	117.8	71.0	117.8	71.0
Multi Tank Conveyor	140.3	72.8	140.3	72.8
High Temperature				
Under Counter	28.9	22.8	18.4	14.5
Stationary Single Tank Door	127.6	88.0	81.2	56.0
Single Tank Conveyor	122.9	98.9	78.2	62.9
Multi Tank Conveyor	205.6	114.5	130.8	72.8
Pot, Pan, and Utensil	69.2	57.4	44.1	36.5

Annual Water Savings Algorithm

$\Delta \text{Water (CCF)} = \text{Water}_{\text{BASE}} - \text{Water}_{\text{EFF}}$

Where

- $\text{Water}_{\text{BASE}}$ = Annual water consumption of baseline unit.
= Values provided in tables below.
- $\text{Water}_{\text{EFF}}$ = Annual water consumption of ENERGY STAR unit.
= Values provided in tables below.

	Annual Water Consumption (CCF) ¹⁴⁰⁷	
	Baseline	ENERGY STAR
Low Temperature		
Under Counter	54.3	37.3

¹⁴⁰⁷ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Stationary Single Tank Door	246.0	138.2
Single Tank Conveyor	219.3	132.2
Multi Tank Conveyor	261.1	135.6
High Temperature		
Under Counter	34.2	27.0
Stationary Single Tank Door	151.1	104.3
Single Tank Conveyor	145.6	117.2
Multi Tank Conveyor	243.5	135.6
Pot, Pan, and Utensil	82.0	68.0

Incremental Cost

The incremental cost for this measure varies based on machine configuration and is listed in the table below.¹⁴⁰⁸

Machine Type		Incremental Cost
Low Temperature	Under Counter	\$50
	Stationary Single Tank Door	\$0
	Single Tank Conveyor	\$0
	Multi Tank Conveyor	\$970
High Temperature	Under Counter	\$120
	Stationary Single Tank Door	\$770
	Single Tank Conveyor	\$2050

¹⁴⁰⁸ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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	Multi Tank Conveyor	\$970
	Pot, Pan, and Utensil	\$1710

Measure Life

The life of a commercial dishwasher varies based on configuration and is listed in the table below.¹⁴⁰⁹

Machine Type	Measure Life (years)
Under Counter	10
Stationary Single Tank Door	15
Single Tank Conveyor	20
Multi Tank Conveyor	20
Pot, Pan, and Utensil	10

Operation and Maintenance Impacts

n/a

¹⁴⁰⁹ Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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Demand Control Commercial Kitchen Ventilation

Unique Measure Code(s): CI_KE_TOS_DCVENT_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure relates to the installation of a demand control kitchen ventilation system (DCKV) in a commercial kitchen. DCKV systems employ active cooking sensors to reduce ventilation rates when the full ventilation capacity is not required. Ventilation is reduced by a variable frequency drives in both exhaust fans and make-up air fans. Savings is realized from both direct fan electrical savings as well as less conditioned air being exhausted.

The methods for calculating savings described here are only to be used on systems where the total controlled ventilation flow (all controlled hoods added together) is 25,000 CFM for less. For larger system a custom analysis is encouraged. This measure applies to retrofit, time of sale, and new construction.

Definition of Baseline Condition

Commercial kitchens typically have only a manual on/off switch, whereby the exhaust hoods and make-up air run at full design capacity.

Definition of Efficient Condition

The efficient system will be capable of at least 50% reduction from the maximum design speed. User controls shall provide a visual indication of a fault in the same room as the unit when the system is bypassed or disabled. Ventilation will be reduced by variable speed drives which are controlled by optical cooking sensors, infrared cooking sensors, temperature-based sensors, and/or direct appliance communication. Optical

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sensors shall be placed in the hood, infrared sensors shall be directed at cooking equipment, and temperature sensors shall be positioned in the hood or duct.

Annual Energy Savings Algorithm

If:

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{cooling}$$
$$\Delta kWh_{fan} = \left(\frac{CFM}{1400^{1410}} \right) * Hours * Days * Weeks * \sum_{0\%}^{100\%} (\%FF * PLR)$$
$$\Delta kWh_{cooling} = SF_{Cool} * \%MUA_{Cool} * \Delta kWh_{fan}$$

Where:

- CFM

= Uncontrolled design hood exhaust flow in cubic feet per minute.

= If actual flow is unknown, estimate flow from hood dimensions.

For unlisted hoods estimate 100 CFM per square foot of plan area.

For UL listed hoods estimate 250 CFM per length of hood in feet.
- Hours

= Hours per day hood is operated.

= If actual hours are unknown, assume 5 hours per meal served.
- Days

= Number of days kitchen is in operation per week.
- Weeks

= Number of weeks kitchen is in operation.

= If actual weeks are unknown assume 50 weeks per year.
- %FF

= Percentage of run-time spent within a given flow fraction range.

= If actual values unknown, assume 30% of time at full flow, 30% of time at 75% flow, and 40% of time at 50% flow.
- PLR

= Part load ratio for a given flow fraction range.

¹⁴¹⁰ Estimation of CFM delivered per kW consumed from both exhaust and make-up air fan motor. Derived from proprietary Navigant DCKW tool.

= For Flow Fractions abvoe 50%, $PLR = \text{Flow fraction}^{(2.5)}$.
Example: for a flow fraction of 75% the $PLR = (0.75)^{2.5} = 0.487$.
Otherwise use PLR table below.

Part Load Ratios by Control and Fan Type and Flow Fraction (PLR)

Control Type	Flow Fraction									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
VFD	0.09	0.10	0.11	0.15	0.20	0.28	0.41	0.57	0.77	1.00

SF_{Cool} = Cooling savings factor.
= 0.471.¹⁴¹¹
 $\%MUA_{Cool}$ = During the cooling season, the percentage of make-up air that is conditioned. If kitchen is cooled, then $\%CMUA = 1.0$. If kitchen is not cooled, then must calculate the percentage of make-up air that is being pulled from the dining room or other conditioned space.
= If actual value is unknown, then assume 30%, or 0.3.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / (\text{Hours} * \text{Days} * \text{Weeks}) * CF$

Where:

¹⁴¹¹ Savings factor calculated from proprietary Navigant DCKW tool using TMY3 temperature data from Baltimore, MD. The tool does a bin hour calculation of the cooling energy required to condition make-up air.

CF = 1.0 if kitchen operates during dinner, 0.0 if the kitchen does not operate during dinner.

Annual Fossil Fuel Savings Algorithm

$\Delta MMBTU = SF_{Heat} * \Delta kWh_{fan}$

Where:
 SF_{Heat} = Heating savings factor from table below. If percent of make-up air from dining room is unknown, assume 30% from dining room.

Heating Savings Factor (SF_{Heat})¹⁴¹²

Percent of Make-up Air from Nearby Conditioned Space (Dining Room)	Make-up Air Directly Supplied to Kitchen is NOT Heated	Make-up Air Directly Supplied to Kitchen is Heated
0%	0	0.0088
10%	0.0013	0.0093
20%	0.0026	0.0097
30%	0.0039	0.0101
40%	0.0042	0.0105
50%	0.0065	0.0109
60%	0.0078	0.0113
70%	0.0091	0.0118

¹⁴¹² Saving factor calculated from proprietary Navigant DCKW tool using TMY3 temperature data from Baltimore, MD. The tool does a bin hour calculation of the heating energy required to condition make-up air.

80%	0.0104	0.0122
90%	0.0117	0.0126
100%	0.0130	0.0130

Annual Water Savings Algorithm

n/a

Incremental Cost

Actual cost must be obtained. For retrofits, be sure to collect labor costs associated with the installation, both mechanical and electrical labor.

Measure Life

The measure life is assumed to be 15 years.¹⁴¹³

Operation and Maintenance Impacts

n/a

¹⁴¹³DEER lifetime for a VFD controlled by a CO2 sensor.
http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx See row 81 of the “Updated 2014 EUL table” tab of the workbook.

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Industrial Equipment

Variable Speed Drive Screw Air Compressors

Unique Measure Code(s): CI_KE_TOS_VSDSCRAIR_0619

Effective Date: June 2019

End Date: TBD

Measure Description

This measure relates to the installation of a new high-efficiency oil-flooded, screw air compressor of 100 HP or less with a variable speed drive. This measure applies to time of sale and new construction.

Definition of Baseline Condition

The baseline condition is a modulating with blow down screw compressor. Baseline compressors choke off the inlet air to modulate the compressor output, resulting in inefficient operation.

Definition of Efficient Condition

A 100 HP or less screw compressor with variable speed control on the motor to match output to the load.

Annual Energy Savings Algorithm

$$\Delta kWh = 0.9^{1414} * HP * HOURS * (COMPF_{base} - COMPF_{ee})$$

Where:

HP = Compressor motor nominal HP

¹⁴¹⁴ Compressor motor nominal HP to full load kW conversion factor.

- HOURS

= Compressor total hours of operation

= If unknown, see “Compressor Total Hours of Operation and Coincidence Factor, if unknown” below.
- COMPF_{base}

= Baseline compressor factor

= See “Baselien Compressor Factor” Table below based on existing baseline compressor type. Where there is no baseline compressor use modulating with blowdown as the baseline type.
- COMPF_{ee}

= Installed compressor factor, actual

= If unknown, 0.705¹⁴¹⁵
- Summer Coincident Peak kW Savings Algorithm
- $\Delta kW = \Delta kWh / HOURS * CF$
- Where:

CF

= Coincidence factor

= If unknown, see “Compressor Total Hours of Operation and Coincidence Factor, if unknown” below.
- Annual Fossil Fuel Savings Algorithm
- n/a
- Annual Water Savings Algorithm
- n/a
- ¹⁴¹⁵ Efficiency Vermont Technical Reference User Manual (TRM) No. 2015-87C..
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Incremental Cost

Incremental cost = (\$127 * HP) + \$1,446¹⁴¹⁶

Measure Life

The measure life is assumed to be 13 years¹⁴¹⁷.

Operation and Maintenance Impacts

n/a

Reference Tables

¹⁴¹⁶ Efficiency Vermont Technical Reference User Manual (TRM) No. 2015-87C.

¹⁴¹⁷ Based on a review of TRM assumptions from New York (January 2019), Massachusetts (October 2015), Illinois (September 2018), Indiana (July 2015), and Vermont (March 2015). Estimates range from 10 to 15 years.

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Compressor Total Hours of Operation and Coincidence Factor, if unknown¹⁴¹⁸

Number of shifts	Operating Hours	Coincidence Factor (CF)
Single shift	1,976 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time	0.59
2 - shift	3,952 7AM – 11 PM, weekdays, minus some holidays and scheduled down time	0.95
3 - shift	5,928 24 hours per day, weekdays, minus some holidays and scheduled down time	0.95
4 - shift	8,320 24 hours per day, 7 days a week minus some holidays and scheduled down time	0.95

Baseline Compressor Factor¹⁴¹⁹

Baseline Compressor	Compressor Factor (COMPF _{base})
Modulating w/ Blowdown	0.890
Load/No Load w/ 1 Gallon-of-storage/CFM _{Max}	0.909
Load/No Load w/ 3 Gallon-of-storage/CFM _{Max}	0.831
Load/No Load w/ 5 Gallon-of-storage/CFM _{Max}	0.806

¹⁴¹⁸ 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0, Volume 2: Commercial and Industrial Measures.

¹⁴¹⁹ Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM. (The “variable speed drive” compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

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A. RETIRED

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B. Description of Unique Measure Codes

Each measure included in the TRM has been assigned a unique identification code. The code consists of a string of five descriptive categories connected by underscores, in the following format:

Sector_End Use_Program Type_Measure_MonthYear

A description of the abbreviations used in the codes is provided in the tables below:

SECTOR	
RS	Residential
CI	Commercial & Industrial
END USE	
LT	Lighting
RF	Refrigeration
HV	Heating, Ventilation, Air Conditioning
WT	Hot Water
LA	Laundry
SL	Shell (Building)
MO	Motors and Drives
KE	Commercial Kitchen Equipment
PL	Plug Load
PROGRAM TYPE	
TOS	Time of Sale
NC	New Construction
RF	Retrofit
EREP	Early Replacement
ERET	Early Retirement
DI	Direct Install

C. RETIRED

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D. Commercial & Industrial Lighting Operating Hours and Coincidence Factors

Downstream Programs¹⁴²⁰

If both building type and space type are available, hours of use and coincidence factors are broken out by building type, then by space type using the following logic:

- Does the building fit into one of the listed building types in Table D-1?
 - Yes: Does the space fit into one of the building type and space type pairs in Table D-1?
 - Yes: Use data from the matching building and space type in Table D-1.
 - No: Does the space fit into one of the space types in Table D-2?
 - Yes: Use data from the matching space type in Table D-2.
 - No: Use data from the matching building type and space type = "Other" in Table D-1.
 - No: Does the space fit into one of the space types in Table D-2?
 - Yes: Use data from the matching space type in Table D-2.
 - No, Use data from building type = "All" and space type = "Other" in Table D-2.

If the Building Type is known, but the Space Type is unknown, the matching Building Type and "Other" Space Type should be used.

If Building Type is unknown, Building Type "All" and "Other" Space Type should be used.

Table D-1: C&I Downstream Lighting Parameters by Building and Space Type¹⁴²¹

Building Type	Space Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
Education	Classroom/Lecture	1,505	0.21	0.22	0.20
Education	Corridor/Hallways	5,052	0.77	0.78	0.75

¹⁴²⁰ Downstream programs are programs where the efficiency program's influence is at the end user level such as prescriptive, custom, or new construction programs.

¹⁴²¹ EmPOWER Maryland DRAFT Final Impact Evaluation Deemed Savings (June 1, 2017 - May 31, 2018) Commercial & Industrial Prescriptive, Small Business, and Direct Install Programs, Navigant, March, 2018.

Building Type	Space Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
Education	Office (Executive/Private)	2,084	0.42	0.57	0.26
Education	Office (General)	4,252	0.66	0.67	0.46
Education	Office(Open Plan)	2,888	0.62	0.70	0.54
Education	Other	2,032	0.33	0.34	0.35
Grocery	Other	6,027	0.84	0.84	0.82
Grocery	Retail Sales/Showroom	7,374	0.98	0.98	0.93
Grocery	Storage (Conditioned & Walk-In Refrigerator/Freezer)	5,851	1.00	0.99	0.98
Health	Corridor/Hallways	6,191	0.90	0.90	0.77
Health	Other	2,964	0.59	0.61	0.41
Office	Corridor/Hallways	4,092	0.65	0.64	0.71
Office	Lobby (Main Entry and Assembly)	6,569	0.93	0.91	0.80
Office	Office (General)	3,009	0.70	0.70	0.48
Office	Other	2,897	0.70	0.69	0.48
Retail	Lobby (Main Entry and Assembly)	6,417	0.99	0.99	0.63
Retail	Office (General)	3,175	0.72	0.73	0.40
Retail	Other	6,679	0.88	0.88	0.65

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Building Type	Space Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
Retail	Restrooms	5,816	0.94	0.94	0.70
Retail	Retail Sales/Showroom	5,192	0.98	0.98	0.64
Warehouse/ Industrial	Auto Repair Workshop	5,482	0.94	0.93	0.49
Warehouse/ Industrial	Comm/Ind Work (General High Bay)	5,103	0.92	0.94	0.86
Warehouse/ Industrial	Comm/Ind Work (General Low Bay)	7,110	0.98	0.98	0.78
Warehouse/ Industrial	Office (General)	2,868	0.74	0.74	0.36
Warehouse/ Industrial	Other	3,338	0.71	0.69	0.44
Warehouse/ Industrial	Restrooms	4,213	0.53	0.53	0.47
Warehouse/ Industrial	Storage (Conditioned & Walk-In Refrigerator/Freezer)	4,530	0.81	0.82	0.40

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Table D-2: C&I Downstream Lighting Parameters by Space Type for Unknown or Unmatched Building Types¹⁴²²

Building Type	Space Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
All	Auto Repair Workshop	6,189	0.88	0.89	0.61
All	Classroom/Lecture	1,584	0.24	0.24	0.20
All	Comm/Ind Work (General High Bay)	4,790	0.90	0.91	0.82
All	Comm/Ind Work (General Low Bay)	6,775	0.95	0.95	0.77
All	Conference Room	1,201	0.28	0.30	0.16
All	Corridor/Hallways	5,670	0.86	0.86	0.73
All	Dining Area	2,962	0.48	0.53	0.51
All	Exercise Centers/Gymnasium	4,833	0.81	0.82	0.60
All	Kitchen/Break room & Food Prep	3,522	0.79	0.74	0.42
All	Library	1,957	0.44	0.46	0.31
All	Loading Dock	7,358	0.97	0.97	0.62
All	Lobby (Main Entry and Assembly)	5,947	0.83	0.82	0.71
All	Lobby (Office Reception/Waiting)	3,425	0.84	0.87	0.49
All	Mechanical/Electrical Room	5,026	0.73	0.74	0.46
All	Office (Executive/Private)	1,753	0.42	0.44	0.20

¹⁴²² EmPOWER Maryland DRAFT Final Impact Evaluation Deemed Savings (June 1, 2017 - May 31, 2018) Commercial & Industrial Prescriptive, Small Business, and Direct Install Programs, Navigant, March, 2018.

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Building Type	Space Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
All	Office (General)	3,001	0.67	0.67	0.43
All	Office(Open Plan)	3,159	0.81	0.82	0.49
All	Other	3,438	0.65	0.64	0.4
All	Parking Garage	8,678	0.98	0.98	0.99
All	Outside/Outdoor Area	3,604	0.11	0.11	0.58
All	Restrooms	2,521	0.48	0.42	0.30
All	Retail Sales/Showroom	6,152	0.97	0.97	0.78
All	Storage (Conditioned & Walk-In Refrigerator/Freezer)	4,672	0.81	0.81	0.44
All	Storage (Unconditioned)	2,930	0.66	0.64	0.40

Hours of use and coincidence factors are taken from the matching building type in Table D-3. If the building type is unknown or unmatched, "Other" building type should be used.

Table D-3: C&I Interior Midstream Lighting Parameters by Building Type

Building Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
Education	2,233	0.35	0.36	0.33
Grocery	7,272	0.97	0.97	0.93
Health	3,817	0.67	0.68	0.51

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Building Type	HOURS	CF _{UPeak}	CF _{PJM-S}	CF _{PJM-W}
Office	3,044	0.70	0.69	0.49
Other	4,058	0.62	0.61	0.46
Retail	4,696	0.83	0.83	0.56
Warehouse/Industrial	4,361	0.80	0.80	0.50

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E. Commercial & Industrial Lighting Waste Heat Factors

Waste Heat Factors for C&I Lighting – Known HVAC Types¹⁴²³

State, Utility	Building Type	Demand Waste Heat Factor (WHFd)		Annual Energy Waste Heat Factor by Cooling/Heating Type (WHFe)			
		AC (Utility)	AC (PJM)	AC/ NonElec	AC/ ElecRes	Heat Pump	NoAC/ ElecRes ¹⁴²⁴
Delaware, All	Office	1.35	1.32	1.10	0.85	0.94	0.75
	Retail	1.27	1.26	1.06	0.83	0.95	0.77
	School	1.44	1.44	1.10	0.81	0.96	0.71
	Warehouse	1.22	1.23	1.02	0.75	0.89	0.73
	Other	1.34	1.32	1.08	0.82	0.93	0.74

Note(s): The “Other” building type should be used when the building type is known but not explicitly listed above. A description of the actual building type should be recorded in the project documentation. If cooling and heating equipment types are unknown or the space is unconditioned, assume WHFd = WHFe = 1.0.

¹⁴²³ EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 - May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014. Values for Washington, D.C. and Delaware assume values from Maryland, Pepco and Maryland, DPL, respectively.

¹⁴²⁴ Waste Heat Factors for “NoAC/ElecRes” estimated as at difference between “AC/ElecRes” and “AC/NonElec” plus one.

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F. Commercial & Industrial Full Load Cooling and Heating Hours

Full load cooling hours and full load heating hours are broken out by building type and geographic location. The building types and locations are indicated in the following tables.

Full Load Cooling Hours by Location and Building Type (HOURS_{COOL})¹⁴²⁵

Space and/or Building Type	Dover, DE	Wilmington, DE
Assembly	937	922
Education - Community College	713	701
Education - Primary School	293	288
Education - Relocatable Classroom	348	342
Education - Secondary School	337	331
Education - University	787	774
Grocery	672	662
Health/Medical - Hospital	1,213	1,194
Health/Medical - Nursing Home	645	634
Lodging - Hotel	1,816	1,787
Manufacturing – Bio Tech/High Tech	867	853
Manufacturing – 1 Shift/Light Industrial	456	449
Multi-Family (Common Areas)	1,509	1,485
Office - Large	727	716
Office - Small	629	619
Restaurant - Fast-Food	724	712
Restaurant - Sit-Down	762	750
Retail - Multistory Large	880	866
Retail - Single-Story Large	904	890

¹⁴²⁵ Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook – Fundamentals. See <http://www.neep.org/file/5550/download?token=6THHJ4D7> for calculations.

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Space and/or Building Type	Dover, DE	Wilmington, DE
Retail - Small	915	901
Storage - Conditioned	243	239
Warehouse - Refrigerated	3,886	3,824

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Full Load Heating Hours by Location and Building Type (HOURS_{HEAT})¹⁴²⁶

Space and/or Building Type	Dover, DE	Wilmington, DE
Assembly	1,114	1,150
Education - Community College	713	736
Education - Primary School	668	689
Education - Relocatable Classroom	647	668
Education - Secondary School	719	742
Education - University	530	546
Grocery	984	1,015
Health/Medical - Hospital	214	221
Health/Medical - Nursing Home	932	962
Lodging - Hotel	2,242	2,313
Manufacturing – Bio Tech/High Tech	146	151
Manufacturing – 1 Shift/Light Industrial	585	603
Multi-Family (Common Areas)	256	264
Office - Large	221	228
Office - Small	440	454
Restaurant - Fast-Food	1,226	1,265
Restaurant - Sit-Down	1,131	1,167
Retail - Multistory Large	591	609
Retail - Single-Story Large	739	762
Retail - Small	622	642
Storage - Conditioned	854	881
Warehouse - Refrigerated	342	353

¹⁴²⁶ Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook – Fundamentals. See <http://www.neep.org/file/5550/download?token=6THHJ4D7> for calculations.

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