REGIONAL EVALUATION,
MEASUREMENT & VERIFICATION FORUM

TRM | MID-ATLANTIC
TECHNICAL REFERENCE MANUAL

MID-ATLANTIC
TECHNICAL REFERENCE MANUAL
VERSION 9

About NEEP

Northeast Energy Efficiency Partnerships Inc. (NEEP) was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency as an essential part of demand-side solutions that enable a sustainable regional energy system.

The Mid-Atlantic Technical Reference Manual is a technical assistance project that originated in the Regional Evaluation, Measurement and Verification Forum (EM&V Forum).The EM&V Forum was facilitated by NEEP to support the transparency, role and credibility of energy efficiency and demand resource savings, costs and emission impacts in current and emerging energy and environmental policies and markets in the Northeast, New York, and the Mid-Atlantic region.

About Shelter Analytics

Shelter Analytics, LLC is dedicated to promoting energy efficiency through planning and integrated design concepts in programs, buildings and businesses. We combine our experience and integrity with innovative approaches to support and improve best-practice methods from planning through implementation.

Northeast Energy Efficiency Partnerships

MID-ATLANTIC
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VERSION 9

May 2019

Prepared by Shelter Analytics

Facilitated and Managed by Northeast Energy Efficiency Partnerships

Table of Contents

PREFACE

NEEP and The Regional EM&V Forum

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Subcommittee for the Mid-Atlantic TRM

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INTRODUCTION

This update to the Technical Reference Manual is the outcome of a NEEP technical assistance project sponsored by Maryland, Delaware and the District of Columbia. The intent of the project was to develop and document in detail common assumptions for significant prescriptive residential and commercial/industrial electric energy efficiency measures savings. Measures were chosen by consensus of the subcommittee and project team. For each measure, the TRM includes either specific deemed values or algorithms[1] 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
- Measure lives.

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

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[1] 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.

- **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.

The TRM is intended to be a flexible and living document. To that end, NEEP, the project sponsors and the TRM authors work together to update it annually with additional measures, modifications to characterizations of existing measures and even removal of some measures when they are no longer relevant to regional efficiency programs

Context

The Forum initiated this project as a benefit to both the Mid-Atlantic States and the overall Forum Region, for the following reasons:

- To improve the credibility and comparability of energy efficiency resources to support state and regional energy, climate change and other environmental policy goals;
- To remove barriers to the participation of energy efficiency resources in regional markets by making EM&V practices and savings assumptions more transparent, understandable and accessible;
- To reduce the cost of EM&V activities by leveraging resources across the region for studies of common interest (where a need for such studies has been identified); and
- To inform the potential development of national EM&V protocols.

This is the ninth generation document that has been prepared for the Mid-Atlantic sponsors, and one of few in the country to serve a multi-jurisdictional audience. For definitions of many energy efficiency terms and acronyms included in the TRM, users of this TRM may want to refer to the EMV Forum Glossary available at: http://neep.org/emv-forum/forum-products-and-guidelines.

It is also recognized that programs mature over time and more evaluation and market-research data have become available over the past few years. In addition, efficiency programs in the region are not identical and either the availability or the results of existing baseline studies and other sources of information can differ across organizations and jurisdictions. Also, different budgets and policy objectives exist, and states may have different EM&V requirements and practices. Given these considerations, the contents of this TRM reflect the consensus agreement and best judgment of project sponsors, managers, and consultants on information that was most useful and appropriate to include within the time, resource, and information constraints of the study.

Approach

This section briefly identifies and describes the process used to develop the TRM. In addition, it provides an overview of some of the considerations and decisions involved in the development of estimates for the many parameters. The development of this TRM required a balance of effectiveness, functionality, and relevance with available sources and research costs.

It is helpful to keep in mind that each measure characterization has numerous components, including retrofit scenario, baseline consumption, annual energy savings, coincident peak demand savings, useful life, and incremental cost.

Thus, the project needed to research and develop literally hundreds of unique assumptions. It is further helpful to keep in mind that because the project served a multijurisdictional audience, it required data requests, review, and consensus decision-making by a subcommittee comprised of project sponsors and other stakeholders. The subcommittee was responsible for review and approval of the products generated in each of the tasks needed to complete the project.

Development of the TRM consisted of the following tasks:

Task 1: Prioritization/Measure Selection.

By design, this TRM focuses on priority prescriptive measures, due to a combination of project resource constraints and the recognition that typically 10 - 20% of a portfolio of efficiency measures (such as lighting, some cooling measures, efficient water heaters) likely account for the large majority (90% or more) of future savings claims from prescriptive measures (i.e., those measures effectively characterized by pre-determined incentive and deemed savings values or algorithms).

Measures are selected on the basis of projected or expected savings from program data by measure type expert judgment and review of other relevant criteria available from regulatory filings and the region’s Program Administrators. Note that some of the measures are variations on other measures (e.g. appliances delivered through a midstream promotional program design and appliances in retrofit programs). Because gas measures were not common to all sponsors, these are not priority measures, but there is consensus that gas measures are appropriate to include. For those measures where fossil fuel savings occur in addition to electricity savings (for example the clothes washer measure), or where either electric or fossil fuel savings could be realized depending on the heating fuel used (for example domestic hot water conservation measures), appropriate MMBTU savings have been provided.

Task 2: Development of Parameters Used to Calculate Impacts.

Development of the contents of the TRM proceeds in two stages. The first stage is research, analysis, and critical review of available information to inform the range of assumptions considered for each parameter and each measure included in the TRM. This is based on a comparative study of many secondary sources including existing TRMs from other jurisdictions, evaluation studies and other local, primary research and data, and information that was developed for the EMV Forum’s Common Methods Project.

The comparative analysis itself is not always as straightforward as it might initially seem because the measures and specific variables included in different jurisdictions’ TRMs are sometimes a little different from each other – in efficiency levels promoted, capacity levels considered, the design of program mechanisms for promoting the measures and various other factors. Thus, the comparative analysis of many assumptions requires calibration to common underlying assumptions. Wherever possible, such underlying assumptions – particularly for region-specific issues such as climate, codes and key baseline issues – are derived from the mid-Atlantic region.

The second stage is development of specific recommendations for specific assumptions or algorithms (informed by the comparative analysis), along with rationales and references for the recommendations. These recommended assumptions identify cases where calculation of savings is required and where options exist (for example two coincidence factor values are provided for central AC measures, based on two definitions of peak coincidence factors) for calculation of impact. They also recommend deemed values where consistency can or should be achieved. The following criteria are used in the process of reviewing and adopting the proposed assumptions and establishing consensus on the final contents of the TRM:

- **Credibility.** The savings estimates and any related estimates of the cost-effectiveness of efficiency investments are credible.
- **Accuracy and completeness.** The individual assumptions or calculation protocols are accurate, and measure characterizations capture the full range of effects on savings.

- **Transparency.** The assumptions are considered by a variety of stakeholders to be transparent – that is, widely known, widely accepted, and developed and refined through an open process that encourages and addresses challenges from a variety of stakeholders.
- **Cost efficiency.** The contents of the TRM addressed all inputs that were within the established project scope and constraints. Sponsors recognize that there are improvements and additions that can be made in future generations of this document.

Additional notes regarding the high-level rationale for extrapolation for Mid-Atlantic estimates from the Northeast and other places are provided below under Use of the TRM.

Task 3: Development of Recommendations for Update.

The purpose of this task was to develop a recommended process for when and how information will be incorporated into the TRM in the future. This task assumes that the process of updating and maintaining the TRM is related to but distinct from processes for verification of annual savings claims by Program Administrators. It further assumes that verification remains the responsibility of individual organizations unlike the multi-sponsor, multi-jurisdictional TRM. The development of these recommendations was based on the following considerations:

- Review processes in other jurisdictions and newly available relevant research and data.

- Expected uses of the TRM. This assumes that the TRM will be used to conduct prospective cost-effectiveness screening of utility programs, to estimate progress towards goals and potentially to support bidding into capacity markets. Note that both the contents of the document and the process and timeline by which it is updated might need to be updated to conform to the PJM requirements, once sponsors have gained additional experience with the capacity market.

- Expected timelines required to implement updates to the TRM parameters and algorithms.

- Processes stakeholders envision for conducting annual reviews of utility program savings as well as program evaluations, and therefore what time frame TRM updates can accommodate these.

- Feasibility of merging or coordinating the Mid-Atlantic protocols with those of other States, such as Pennsylvania, New Jersey or entire the Northeast.

Task 4: Delivery of Draft and Final Product.

The final content of the TRM reflects the consensus approval of the results from Task 2 as modified following a peer review. By design, the final version of the TRM document is similar to other TRMs currently available, for ease of comparison and update and potential merging with others in the future.

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 Mid-Atlantic 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 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.
- 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.[2]

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[2] 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.

- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and 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.[3]
- For some of the whole-building program designs that are being planned or implemented in the Mid-Atlantic, 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:

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 it’s life (i.e., replace on burnout), or purchase of new equipment. In cases where a new contruction 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.

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[3] They are captured for lighting and some motor-related measures.

Baseline Condition	Attributes
	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 *upgrades* or enhances existing equipment. Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life. Efficient Case = Post-retrofit efficiency of equipment. Example: Air sealing, insulation, and controls.
Early Replacement (EREP)	Definition: A program that *replaces* existing, operational equipment.[4] Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the remaining life of the existing equipment is over. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Refrigerators and freezers.
Early Retirement (ERET)	Definition: A program that *retires* inefficient, operational duplicative equipment or inefficient equipment that might otherwise be resold. Baseline = The existing equipment, which is retired and not replaced. Efficient Case = Assumes zero consumption since the unit is retired. Example: Appliance recycling.
Direct Install (DI)	Definition: A program where measures are installed during a site visit. Baseline = Existing equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Lighting and low-flow hot water measures

Going forward, the project sponsors can use this TRM, along with other Forum products on common EM&V terminology, guidelines on common evaluation methods, and common reporting formats, along with the experience gained from implementation of the efficiency programs to inform decisions about what savings assumptions should be updated and how.

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.

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[4] 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.

Time of Sale and New Construction Incremental Costs

Calculations of Time of Sale and New Construction incremental costs in the Mid-Atlantic 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

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 Mid-Atlantic 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, Michals 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.

TRM Update History

Version	Issued
1.1	October 2010
1.2	March 2011
2.0	July 2011
3.0	January 2013
4.0	June 2014
5.0	June 2015
6.0	May 2016
7.0	May 2017
7.5	October 2017
8.0	May 2018
9.0	May 2019

RESIDENTIAL MARKET SECTOR

Lighting End Use

Solid State Lighting (LED) Recessed Downlight Luminaire

Unique Measure Code: RS_LT_TOS_SSLDWN_0415, RS_LT_EREP_SSLDWN_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 specification[5]. 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).

Definition of Baseline Condition

The baseline is the purchase and installation of a standard BR30-type incandescent downlight light bulb.

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

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

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[5] ENERGY STAR specification can be viewed here: https://www.energystar.gov/sites/default/files/asset/document/Luminaires%20V2%200%20Final.pdf

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 65W.* [6] *The table also shows the baseline shift from the EISA backstop taking effect in 2020. See the "Baseline Adjustment" section below for how to apply the adjustment factors.*[7]

Lower Lumen Range	Upper Lumen Range	2017-2019 WattsBase	2020+ WattsBase	Baseline Shift (ENERGY STAR>=90 CRI)	Baseline Shift (ENERGY STAR <90 CRI)
400	449	40	9	7%	10%
450	499	45	10	7%	10%
500	649	50	14	10%	13%
650	1419	65	23	12%	16%

WattsEE = *Connected load of efficient lamp*

= *Actual. If unknown assume 9.2W* [8]

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

= *1.0*[9]

HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.86	679[10]
Multi Family Common Areas	16.3	5,950[11]

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[6] Baseline wattage based on common 65 Watt BR30 incandescent bulb (e.g. http://www.destinationlighting.com/storeitem.jhtml?iid=16926)

[7] 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).

[8] 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.

[9] Based upon recommendation in NEEP EMV Emerging Tech Research Report.

[10] 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.

[11] 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

Installation Location	Daily Hours	Annual Hours
Unknown	1.86	679

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

	$WHFe_{Cool}$
Building with cooling	1.087[12]
Building without cooling or exterior	1.0
Unknown	1.077[13]

$WHFe_{Heat}$ = *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 / ηHeat) * %ElecHeat)

If unknown assume 0.899[14]

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

= *47%*[15] *for interior or unknown location*

= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*

= *actual. If not available, use*[16]*:*

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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.

[12] 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).

[13] 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.).

[14] Calculated using defaults; 1+ ((0.47/1.74) * 0.375) = 0.899

[15] 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.

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[17]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[18]

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

$$\Delta kWh = ((65 - 9.2) / 1{,}000) * 1.0 * 679 * (0.899 + (1.077 - 1))$$

$$= 37.0 \text{ kWh}$$

Multi Family Common Areas

$$\Delta kWh = ((65 - 9.2) / 1{,}000) * 1.0 * 5950 * (0.899 + (1.077 - 1))$$

$$= 324 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

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[16] 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.

[17] 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.

[18] 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*[19]
Building without cooling	1.0
Unknown	*1.17*[20]

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[21]
	PJM CF	0.058[22]
Multi Family Common Areas	PJM CF	0.86[23]
Unknown	Utility Peak CF	0.059
	PJM CF	0.058

Illustrative example – do not use as default assumption

ΔkW_{PJM} = ((65 – 9.2) / 1,000) * 1.0 * 1.17 * 0.058

= 0.0038 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):

ΔMMBTUPenalty[24] = - ((((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.003412) / ηHeat) * %FossilHeat

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[19] 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).

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

[21] Based on Navigant Consulting "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 15.

[22] Ibid.

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

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

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[25] *for interior or unknown location*
= *0% for exterior or unheated location*
0.003412 =*Converts kWh to MMBTU*
ηHeat = *Efficiency of heating system*
=*80%*[26]
%FossilHeat = *Percentage of home with non-electric heat*

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[27]

Illustrative example – do not use as default assumption

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

ΔMMBTUPenalty = - (((65 – 9.2)/1000) * 1.0 * 679 * 0.47 * 0.003412/0.75) * 1.0

= - 0.08 MMBTU

If home heating fuel is unknown:

ΔMMBTUPenalty = - (((65 - 9.2)/1000) * 1.0 * 679 * 0.47 * 0.003412/0.80) * 0.625

= - 0.047 MMBTU

Annual Water Savings Algorithm

n/a

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[25] 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.

[26] Minimum federal standard for residential furnaces.

[27] Based on KEMA baseline study for Maryland.

Incremental Cost

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.[28] 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.[29]

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
Component Life[30] (years) Residential interior and in-unit Multi Family or unknown.	2.95[31]
Multi Family Common Areas	0.34[32]

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.

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[28] 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.

[29] 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.

[30] Based on lamp life / assumed annual run hours.

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

[32] Calculated as 2000/5950 = 0.34 years.

Baseline Adjustment

To account for the EISA “backstop” going into effect in 2020, the savings for this measure should be reduced to account for increased baseline efficacy requirements. As of 1/1/2020, the EISA backstop requires that all general service lamps meet or exceed an efficacy requirement of 45 lumens per watt. 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.[33] Therefore, for selected lamp types, the annual savings as of 1/1/2020 should be adjusted downward to account for the increased baselines. Consistent with the ENERGY STAR V2.0 specifications, the baseline watts table above shows the calculated savings adjustments for two CRI tiers. Using the appropriate adjustment factor based on the baseline lamp type and ENERGY STAR LED CRI, the energy savings are calculated as follows:

Post 1/1/2020 ΔkWh[34] = ΔkWh * Baseline_Shift

Similarly, adjusted summer coincident peak kW savings and annual fossil fuel savings are calculated as follows:

Post 1/1/2020 ΔkW = ΔkW * Baseline_Shift

Post 1/1/2020 ΔMMBTUPenalty = ΔMMBTUPenalty * Baseline_Shift

Illustrative example – do not use as default assumption

Residential interior and in-unit Multi Family with CRI=90
Post 1/1/2020 ΔkWh = 50.1 kWh (as calculated above) * 12%
= 6.0 kWh

Therefore, assuming this lamp is installed in 2018 and has a measure life of 20 years, the adjusted lifetime savings would be:

$\Delta kWh_{Lifetime}$ = 2 * 50.1 kWh + 18 * 6 kWh = 208.2 kWh

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[33] 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).

[34] To simplify the calculations, this algorithm assumes that the pre-2020 baseline lamp would need to be replaced in 2020.

Alternatively, the Post 1/1/2020 savings may be estimated by substituting the "2020+ WattsBase" value from the lumen equivalence table above into the appropriate savings algorithm.

Illustrative example – do not use as default assumption

Residential interior and in-unit Multi Family with CRI=90

Post 1/1/2020 $\Delta kWh = ((WattsBase - WattsEE) /1{,}000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} - 1))$

$= ((23 - 9.2) / 1{,}000) * 1.0 * 920 * (0.899 + (1.077 - 1))$

$= 12.4$ kWh

Therefore, assuming this lamp is installed in 2018 and has a measure life of 20 years, the adjusted lifetime savings would be:

$\Delta kWh_{Lifetime} = 2 * 50.1 \text{ kWh} + 18 * 12.4 \text{ kWh} = 323.4 \text{ kWh}$

ENERGY STAR Integrated Screw Based SSL (LED) Lamp

Unique Measure Code: RS_LT_TOS_SSLDWN_0619, RS_LT_EREP_SSLDWN_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 socket[35]. 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 specifications can be viewed here: http://1.usa.gov/1QJFLgT

Annual Energy Savings Algorithm

$\Delta kWh = ((WattsBase - WattsEE) /1000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} – 1))$

Where: **For all lamps EXCEPT: PAR, MR and MRX**

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 how to apply the adjustment factors.[36]

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

[36] 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	2017-2019 WattsBase	2020+ WattsBase	Baseline_Shift (ENERGY STAR CRI>=90)	Baseline_Shift (ENERGY STAR CRI<90)
Omnidirectional, Medium Screw Base Lamps (A, BT, P, PS, S or T) (†, ◊see exceptions below)	250	309	25	25	100%	100%
	310	749	29	12	20%	23%
	750	1049	43	20	24%	28%
	1050	1489	53	28	29%	33%
	1490	2600	72	46	38%	43%
	2601	3300	150	66	22%	25%
	3301	3999	200	200	100%	100%
	4000	6000	300	300	100%	100%
†S Shape <=749 lumens and T Shape <=749 lumens or T>10" length)	250	309	25	25	100%	100%
	310	749	40	12	13%	15%
Decorative, Medium Screw Base (G Shape) (‡see exceptions below)	250	309	25	25	100%	100%
	310	749	29	12	17%	17%
	750	1049	43	20	21%	21%
	1050	1300	53	26	23%	23%
‡G16-1/2, G25, G30 <=499 lumens	250	309	25	25	100%	100%
	310	349	25	7	11%	11%
	350	499	40	9	9%	9%
‡G Shape with diameter >=5"	250	349	25	25	100%	100%
	350	499	40	40	100%	100%
	500	574	60	60	100%	100%
	575	649	75	75	100%	100%
	650	1099	100	100	100%	100%
	1100	1300	150	150	100%	100%
Decorative, Medium Screw Base (B, BA, C, CA, DC, and F, and ST) (*see exceptions below)	70	89	10	10	100%	100%
	90	149	15	15	100%	100%
	150	299	25	25	100%	100%
	300	309	40	40	100%	100%
	310	499	29	9	12%	12%
	500	699	29	13	21%	21%
*B, BA, CA, and F <=499 lumens	70	89	10	10	100%	100%
	90	149	15	15	100%	100%
	150	299	25	25	100%	100%
	300	309	40	40	100%	100%

	Lower Lumen Range	Upper Lumen Range	2017-2019 WattsBase	2020+ WattsBase	Baseline_Shift (ENERGY STAR CRI>=90)	Baseline_Shift (ENERGY STAR CRI<90)
	310	499	40	9	8%	8%
Omnidirectional, Intermediate Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	25	25	100%	100%
	310	749	40	12	13%	15%
†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	25	100%	100%
	310	749	40	40	100%	100%
Decorative, Intermediate Screw Base (G Shape) (‡see exceptions below)	250	309	25	25	100%	100%
	310	349	25	7	11%	11%
	350	499	40	9	9%	9%
‡G Shape with first numeral less than 12.5 or with diameter >=5"	250	349	25	25	100%	100%
	350	499	40	40	100%	100%
Decorative, Intermediate Screw Base (B, BA, C, CA, DC, and F, and ST)	70	89	10	10	100%	100%
	90	149	15	15	100%	100%
	150	299	25	25	100%	100%
	300	309	40	40	100%	100%
	310	499	40	9	8%	8%
Omnidirectional, Candelabra Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	25	25	100%	100%
	310	749	40	12	13%	15%
	750	1049	60	20	15%	18%
†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	25	100%	100%
	310	749	40	40	100%	100%
	750	1049	60	60	100%	100%
Decorative, Candelabra Screw Base (G Shape) (‡see exceptions below)	250	309	25	25	100%	100%
	310	349	25	7	11%	11%
	350	499	40	9	9%	9%
	500	574	60	12	7%	7%

	Lower Lumen Range	Upper Lumen Range	2017-2019 WattsBase	2020+ WattsBase	Baseline_Shift (ENERGY STAR CRI>=90)	Baseline_Shift (ENERGY STAR CRI<90)
‡G Shape with first numeral less than 12.5 or with diameter >=5"	250	349	25	25	100%	100%
	350	499	40	40	100%	100%
	500	574	60	60	100%	100%
Decorative, Candelabra Screw Base (B, BA, C, CA, DC, and F, and ST)	70	89	10	10	100%	100%
	90	149	15	15	100%	100%
	150	299	25	25	100%	100%
	300	309	40	40	100%	100%
	310	499	40	9	8%	8%
	500	699	60	13	8%	8%
Directional, Medium Screw Base, w/diameter <=2.25"	400	449	40	9	7%	10%
	450	499	45	10	7%	10%
	500	649	50	13	8%	11%
	650	1199	65	20	11%	14%
Directional, Medium Screw Base, R, , ER, BR, BPAR or similar bulb shapes w/ diameter >2.5 " (**see exceptions below)	640	739	40	15	14%	18%
	740	849	45	18	14%	19%
	850	1179	50	22	18%	23%
	1180	1419	65	29	17%	22%
	1420	1789	75	36	19%	24%
	1790	2049	90	43	19%	24%
	2050	2579	100	51	22%	27%
	2580	3300	120	65	24%	30%
	3301	3429	120	120	100%	100%
	3430	4270	150	150	100%	100%
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	40	13	11%	15%
	630	719	45	15	11%	15%
	720	999	50	19	14%	18%
	1000	1199	65	24	14%	18%
	1200	1519	75	30	15%	19%
	1520	1729	90	36	15%	19%
	1730	2189	100	44	17%	22%
	2190	2899	120	56	19%	24%
	2900	3300	120	69	26%	32%
	3301	3850	150	150	100%	100%
**ER30, BR30, BR40, or ER40	400	449	40	9	7%	10%
	450	499	45	10	7%	10%

	Lower Lumen Range	Upper Lumen Range	2017-2019 WattsBase	2020+ WattsBase	Baseline_Shift (ENERGY STAR CRI>=90)	Baseline_Shift (ENERGY STAR CRI<90)
	500	649-1179	50	14	10%	13%
**BR30, BR40, or ER40	650	1419	65	23	12%	16%
**R20	400	449	40	9	7%	10%
	450	719	45	13	10%	13%
**All reflector lamps below lumen ranges specified above	200	299	20	20	100%	100%
	300	399-639	30	9	10%	13%
◊Rough service, shatter resistant, 3-way incandescent, and vibration service	250	309	25	25	100%	100%
	310	749	40	12	13%	15%
	750	1049	60	20	15%	18%
	1050	1489	75	28	18%	21%
	1490	2600	100	46	23%	27%
	2601	3300	150	66	22%	25%
	3301	3999	200	200	100%	100%
	4000	6000	300	300	100%	100%

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 tool[37] to verify the lamp meets minimum lumen requirements for the claimed base equivalent Watts. If CBCP and 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.[38] 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:

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[37]

[38] 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.

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 [39]

WattsEE = *Actual LED wattage*
ISR = *In Service Rate or percentage of units rebated that get installed.*
= *0.98*[40]
HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.86	679[41]
Multi Family Common Areas	16.3	5,950[42]
Exterior	4.5	1,643[43]
Unknown	1.86	679[44]

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[39] Ibid.

[40] 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

[41] 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.

[42] 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.

[43] 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

[44] "Unknown" assumes a residential interior or in-unit multifamily application.

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

	$WHFe_{Cool}$
Building with cooling	1.087[45]
Building without cooling or exterior	1.0
Unknown	1.077[46]

$WHFe_{Heat}$ = *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 / ηHeat) * %ElecHeat). *If unknown assume 0.899*[47]

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

= 47%[48] *for interior or unknown location*

= 0% for exterior or unheated location

ηHeat = *Efficiency in COP of Heating equipment*

= actual. If not available, use[49]*:*

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)

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[45] 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).

[46] 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.).

[47] Calculated using defaults; 1 + ((0.47/1.74) * 0.375) = 0.899

[48] 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.

[49] 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.

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[50]

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[51]

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.

ΔkWh = ((50 - 10)/ 1,000) * 0.98 * 679 * (0.899 + (1.077 – 1))

= 26.0 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((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*[52]
Building without cooling or exterior	1.0
Unknown	*1.17*[53]

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[50] 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.

[51] Based on KEMA baseline study for Maryland.

[52] 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).

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

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[54]
	PJM CF	0.058[55]
Multi Family Common Areas	PJM CF	0.86[56]
Exterior	PJM CF	0.018[57]
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.

$$\Delta kW_{PJM} = ((50 – 10)/ 1,000) * 0.98 * 1.17 * 0.058$$

$$= 0.0027 \text{ kW}$$

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):

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

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 47%[58] *for interior or unknown location*

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[54] Based on Navigant Consulting "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 15

[55] Ibid.

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

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

[58] 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.

= 0% for exterior or unheated location

0.003412 =Converts kWh to MMBTU

ηHeat = Efficiency of heating system

=80%[59]

%FossilHeat = Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[60]

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.

$$\Delta \text{MMBTUPenalty} = - ((50 - 10)/ 1{,}000) * 0.98 * 679 * 0.47 * 0.003412/0.80) * 0.625$$

$$= - 0.033 \text{ MMBTU}$$

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.[61]

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.

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[59] Minimum federal standard for residential furnaces.

[60] Based on KEMA baseline study for Maryland.

[61] Adapted from analysis provided by Apex Analytics LLC in April 2018.

	Measure Life, Energy Star V2.0				
	Rated Life[62]	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[63]	20	2.52	9.1	13.6

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 2012-2014 Compliant	EISA 2020 Compliant
Replacement Cost Unknown	$1.58	$1.67
Replacement Cost, Globe	$1.67	$6.18
Replacement Cost, Reflector	$3.57	$1.99
Replacement Cost, A Lamp	$1.52	$3.10
Replacement Cost, Candelabra	$1.04	$3.45
Component Life (hours)	1,000	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	$.71	$6.18	$4.55

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[62] 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.

[63] ENERGY STAR V2.1 specifications reduce rated life requirements to 15,000 hours for directional lamps.

Baseline Adjustment

To account for the EISA “backstop” going into effect in 2020, the savings for this measure should be reduced to account for increased baseline efficacy requirements. As of 1/1/2020, the EISA backstop requires that all general service lamps meet or exceed an efficacy requirement of 45 lumens per watt. 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.[64] Therefore, for selected lamp types, the annual savings as of 1/1/2020 should be adjusted downward to account for the increased baselines. Consistent with the ENERGY STAR V2.0 specifications, the baseline watts table above shows the calculated savings adjustments for two CRI tiers. Using the appropriate adjustment factor based on the baseline lamp type and ENERGY STAR LED CRI, the energy savings are calculated as follows:

Post 1/1/2020 ΔkWh[65] = ΔkWh * Baseline_Shift

Similarly, adjusted summer coincident peak kW savings and annual fossil fuel savings are calculated as follows:

Post 1/1/2020 ΔkW = ΔkW * Baseline_Shift

Post 1/1/2020 ΔMMBTUPenalty = ΔMMBTUPenalty * Baseline_Shift

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" and CRI=90 is installed in a residential interior location.

Post 1/1/2020 ΔkWh = 35.2 kWh (as calculated above) * 8%
= 2.8 kWh

Therefore, assuming this lamp is installed in 2018 and has a measure life of 16.3 years, the adjusted lifetime savings would be:

$\Delta kWh_{Lifetime}$ = 2 * 35.2 kWh + 14.3 * 2.8 kWh = 110.6 kWh

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[64] 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).

[65] To simplify the calculations, this algorithm assumes that the pre-2020 baseline lamp would need to be replaced in 2020.

Alternatively, the Post 1/1/2020 savings may be estimated by substituting the "2020+ WattsBase" value from the lumen equivalence table above into the appropriate savings algorithm.

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" and CRI=90 is installed in a residential interior location.

Post 1/1/2020 $\Delta kWh = ((WattsBase_{2020+} - WattsEE) /1000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} – 1))$

$= ((13 -10)/1,000) * 0.98 * 920 * (0.899 + (1.077 – 1))$

$= 2.6$ kWh

Therefore, assuming this lamp is installed in 2018 and has a measure life of 16.3 years, the adjusted lifetime savings would be:

$\Delta kWh_{Lifetime} = 2 * 35.2$ kWh $+ 14.3 * 2.6$ kWh $= 107.6$ kWh

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

$$\Delta kWh = kWconnected * HOURS * SVGe * ISR * (WHFe_{Heat} + (WHFe_{Cool} - 1))$$

Where:

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

Number of lamps in space with control (A)	Average lamp wattage (B)	kWconnected (AxB)
6.8[66]	0.034[67]	0.230

HOURS = Average hours of use per day. If space type is known, then use average of efficient and inefficient hours of use below[68]:

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[66] 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.

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

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
Living Room	1.9
Mechanical	0.2
Office	3.2
Other	0.9

If space type is not knowm, then assume:

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.66[69]	604[70]
Multi Family Common Areas	16.3	5,950[71]

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[68] Based on Navigant Consulting, "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 14.

[69] 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.).

[70] 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.).

[71] 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

Unknown	1.66[72]	604[73]

SVGe = *Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
= *30%* [74]

ISR = *In Service Rate or percentage of units rebated that get installed*
= *1.00* [75]

$WHFe_{Heat}$ = *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 / ηHeat) * %ElecHeat)

If unknown assume 0.899[76]

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[77] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available, use*[78]*:*

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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

[72] "Unknown" assumes a residential interior or in-unit multifamily application.

[73] "Unknown" assumes a residential interior or in-unit multifamily application.

[74] 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.

[75] 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.

[76] Calculated using defaults; 1 + ((0.47/1.74) * 0.375) = 0.899

[77] 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.

[78] 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.

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[79]

%ElecHeat = Percentage of homes with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[80]

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

	$WHFe_{Cool}$
Building with cooling	1.087[81]
Building without cooling or exterior	1.0
Unknown	1.077[82]

Summer Coincident Peak kW Savings Algorithm

ΔkW = kWconnected * SVGd * ISR * WHFd * CF

Where:

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[79] 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.

[80] Based on KEMA Maryland Energy Baseline Study. Feb 2011

[81] 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).

[82] 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.).

SVGd = *Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.*
= *30%*[83]

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

	WHFd
Building with cooling	*1.19*[84]
Building without cooling or exterior	1.0
Unknown	*1.17*[85]

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[86]
	PJM CF	0.058[87]
Multi Family Common Areas	PJM CF	0.86[88]
Exterior	PJM CF	0.018[89]
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):

$$\Delta MMBTUPenalty = kWconnected * HOURS * SVGe * ISR * HF * 0.003412)/ \eta Heat)$$

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[83] Assumed to be the same as the energy savings percentage (SVGe).

[84] 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).

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

[86] Based on Navigant Consulting "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 15

[87] Ibid.

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

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

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[90] *for interior or unknown location*
= *0% for exterior or unheated location*
0.003412 =*Converts kWh to MMBTU*
ηHeat = *Efficiency of heating system*
=*80%*[91]
%FossilHeat = *Percentage of home with non-electric heat*

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[92]

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure is assumed to be $25 for per control.[93]

Measure Life

The measure life is assumed to be 10 years.[94]

Operation and Maintenance Impacts

n/a

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[90] 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.
[91] Minimum federal standard for residential furnaces.
[92] Based on KEMA Maryland Energy Baseline Study. Feb 2011.
[93] Costs are from 3/28/18 webscraping of homedepot.com for Landsdowne, MD.
[94] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

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

$$\Delta kWh = \mathit{WattsEE} * HOURS * SVGe * ISR * (WHFe_{Heat} + (WHFe_{Cool} - 1)) - Standby_{kWh}$$

Where:

WattsEE = Actual LED wattage.

HOURS = Average hours of use per year:

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	1.86	679[95]
Multi Family Common Areas	16.3	5,950[96]

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[95] 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.

[96] 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

Unknown	1.86	679[97]

SVGe = *Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
= 0.49 [98]

ISR = *In Service Rate or percentage of units rebated that get installed.*
= 0.98[99]

$WHFe_{Heat}$ = *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 / ηHeat) * %ElecHeat)

If unknown assume 0.899[100]

HF = *Heating Factor or percentage of light savings that must be heated*
= 47%[101] *for interior or unknown location*
= 0% for exterior or unheated location

ηHeat = *Efficiency in COP of Heating equipment*
= actual. If not available, use[102]*:*

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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.

[97] "Unknown" assumes a residential interior or in-unit multifamily application.

[98] 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.

[99] 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

[100] Calculated using defaults; 1 + ((0.47/1.74) * 0.375) = 0.899

[101] 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.

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[103]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[104]

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

	$WHFe_{Cool}$
Building with cooling	1.087[105]
Building without cooling or exterior	1.0
Unknown	1.077[106]

$Standby_{kWh}$ = *Standby power draw of the controlled lamp. Use actual value from manufacturer specification. If not know then assume:*

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[102] 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.

[103] 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.

[104] Based on KEMA Maryland Energy Baseline Study. Feb 2011

[105] 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).

[106] 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.).

$$=0.0004^{107} \times 8760 \times 75\%^{108} = 2.63 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kWconnected * SVGd * ISR * WHFd * CF$$

Where:

SVGd = *Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.*
$= 0.49^{109}$

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

	WHFd
Building with cooling	*1.19*[110]
Building without cooling or exterior	1.0
Unknown	*1.17*[111]

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[112]
	PJM CF	0.058[113]
Multi Family Common Areas	PJM CF	0.86[114]
Exterior	PJM CF	0.018[115]
Unknown	Utility Peak CF	0.059

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[107] 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.

[108] Lockheed Martin Energy. op. cit. p32.

[109] See footnote 4.

[110] 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).

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

[112] Based on Navigant Consulting "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 15

[113] Ibid.

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

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

Installation Location	Type	Coincidence Factor (CF)
	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):

$$\Delta MMBTUPenalty = kWconnected * HOURS * SVGe * ISR * HF * 0.003412) / \eta Heat)$$

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[116] *for interior or unknown location*
= *0% for exterior or unheated location*

0.003412 =*Converts kWh to MMBTU*

ηHeat = *Efficiency of heating system*
=*80%*[117]

%FossilHeat = *Percentage of home with non-electric heat*

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[118]

Annual Water Savings Algorithm

n/a

Incremental Cost

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[116] 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.

[117] Minimum federal standard for residential furnaces.

[118] Based on KEMA Maryland Energy Baseline Study. Feb 2011

The lifecycle NPV incremental cost for this retrofit measure is assumed to be $11.[119]

Measure Life

The measure life is assumed to be 15 years.[120]

Operation and Maintenance Impacts

n/a

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[119] 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.

[120] 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.

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 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):[121]

Product Category	Federal Baseline Maximum Energy Usage in kWh/year[122]	ENERGY STAR Maximum Energy Usage in kWh/year[123]
Upright Freezers	8.62*AV+228.3	7.76*AV+205.5
Chest Freezers	7.29*AV+107.8	6.56*AV+97.0

Note that this characterization only specifies gross savings. It is up to the individual program administrators and stakeholders to use proper net to gross ratios.

Definition of Baseline Condition

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 ENERGY STAR, as calculated above, or meeting the next tier promoted by RPP, which is 5% more efficient than the EnergyStar minimum.

Annual Energy Savings Algorithm

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[121] http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746

[122] https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

[123] http://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf

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

Where:

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

Product Category[124]	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%
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 values[125].

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23 [126]

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[124] Savings values come from Energy Star Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

[125] 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.

[126] 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.

LSAF = Load Shape Adjustment Factor
= 1.15 [127]

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 freezer[128].

Measure Life

The measure life is assumed to be 11 years[129].

Operation and Maintenance Impacts

n/a

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[127] 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).

[128] 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

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

Refrigerator, Time of Sale

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

Measure Description

This measure relates to the purchase and installation of a new refrigerator meeting either ENERGY STAR 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.[130] 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[131]
1. Refrigerators and Refrigerator-freezers with manual defrost	6.79AV + 193.6
2. Refrigerator-Freezer--partial automatic defrost	7.99AV + 225.0
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

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

[131] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

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

$$\Delta kWh = kWhBASE * ES$$

Where:

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

ES = 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:

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

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8[132]:

Product Category	New Baseline UEC_{BASE}	New Efficient UEC_{EE}			ΔkWh			Product Category Weighting (%)
		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

---

[132] Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft^3 fresh volume and 6.76 ft^3 freezer volume.

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

If product category shares are unknown [133] 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
= 1.23 [134]

LSAF = Load Shape Adjustment Factor

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[133] 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). Projected product class market shares from pages 9-12 for year 2014. See 'Refrigerator default calcs.xls' for more details.

[134] 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.

= 1.15 [135]

If volume is unknown, use the following defaults:

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

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[135] 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).

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.[136]

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
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.[137]

Operation and Maintenance Impacts

n/a

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[136] 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.

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

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 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

Remaining life of existing unit (first 4 years[138])

$$\Delta kWh = kWhEXIST - kWhEE$$

Remaining measure life (next 8 years)

$$\Delta kWh = kWhBASE - kWhEE$$

---

[138] Assumed to be 1/3 of the measure life.

Where:

kWhEXIST = *Annual energy consumption of existing unit*
= *1146* [139]

kWhBASE = *Annual energy consumption of new baseline unit*

= *511.7*[140]

kWhEE = *Annual energy consumption of ENERGY STAR unit*
=
= *460.8*[141]

Or = *Annual energy consumption of CEE Tier 2 unit*
= *435.2*[142]

Or=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[143]
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

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

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

[140] 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). Projected product class market shares from pages 9-12 for year 2014. See 'Refrigerator default calcs.xls' for more details.

[141] kWh assumptions based on using the ENERGY STAR algorithms in each product class and calculating a weighted average of the different configurations.

[142] kWh assumptions based on 15% less than baseline consumption and calculating a weighted average of the different configurations.

[143] 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.

Where:

TAF = Temperature Adjustment Factor
= 1.23 [144]

LSAF = Load Shape Adjustment Factor
= 1.15 [145]

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

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.[146]

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[144] 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.

[145] 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).

[146] 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

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
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. [147]

Operation and Maintenance Impacts

n/a

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

Refrigerator and Freezer, Early Retirement

Unique Measure Code(s): RS_RF_ERET_REFRIG_0414, RS_RF_ERET_FREEZE_0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure involves the removal of an existing inefficient refrigerator[148] 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 unit[149].

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

Refrigerators:

Energy savings for retired refrigerators are based upon a linear regression model using the following coefficients[150]:

Independent Variable Description	Estimate Coefficient
Intercept	0.80460
Age (years)	0.02107
Pre-1990 (=1 if manufactured pre-1990)	1.03605

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[148] 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.

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

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

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

ΔkWh = [0.80460 + (Age * 0.02107) + (Pre-1990 * 1.03605) + (Size * 0.05930) + (Single-Door * -1.75138) + (Side-by-side * 1.11963) + (Primary * 0.55990) + (HDD/365.25 * Unconditioned * -0.04013) + (CDD/365.25 * Unconditioned * 0.02622)] * 365.25 * Part Use

Where:

HDD = *Heating Degree Days*
= dependent on location. Use actual for location or defaults below[151]

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 below[152]

Location	*Cooling Degree Days (65°F set point)*	*CDD / 365.25*

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[151] 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.

[152] Ibid.

Wilmington, DE	*1,162*	*3.2*
Baltimore, MD	*1,266*	*3.5*
Washington, DC	*1,431*	*3.9*

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.*[153]

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:

$$\Delta kWh = [0.80460 + (18.61 * 0.02107) + (0.20 * 1.03605) + (19.43 * 0.05930) + (0.02 * -1.75138) + (0.34 * 1.11963) + (0.64 * 0.55990) + (2.91 * -0.04013) + (0.77 * 0.02622)] * 365.25 * 0.95$$

$$= 1,098 \text{ kWh}$$

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients[154]:

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

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[153] Based on EmPower DRAFT EY6 Participant Survey Results: Appliance Recycling Program Report

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

Interaction: Located in Unconditioned Space x CDD/365.25	0.08217

ΔkWh = [-0.95470 + (Age * 0.04536) + (Pre-1990 * 0.54341) + (Size * 0.12023) + (Chest Freezer * 0.29816) + (HDDs/365.25 * Unconditioned * -0.03148) + (CDDs/365.25 * Unconditioned * 0.08217)] * 365.25 * 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:

ΔkWh = [-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 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (ΔkWh/8760) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor
= 1.23 [155]
LSAF = Load Shape Adjustment Factor
= 1.066 [156]

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

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[155] 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.

[156] 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.

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:

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

$$= 0.107 \text{ kW}$$

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 recyling of the secondary refrigerator.

Measure Life

The measure life is assumed to be 8 Years.[157]

Operation and Maintenance Impacts

n/a

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[157] KEMA “Residential refrigerator recycling ninth year retention study”, 2004.

Heating Ventilation and Air Conditioning (HVAC) End Use

Central Furnace Efficient Fan Motor

Unique Measure Code(s): RS_HV_RF_FANMTR_0518, RS_HV_TOS_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 could apply to fan motors installed with a furnace or with a central air conditioning unit and could apply when retrofitting an existing unit or installing a new one.

If a new unit is installed, the program should require that it meet ENERGY STAR efficiency criteria in order to qualify for the incentive. Savings estimations below relate only to the changes in energy use associated with an upgrade to an efficient fan motor. These changes include a kWh savings due to reduction in fan power, and a heating fuel penalty because fan waste heat energy contributes to heating the air stream.

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.

When an efficient fan motor is installed as part of a new HVAC system, and savings are claimed based on thermal efficiency of that system, then do not claim fan motor savings separately as motor heating and cooling energy savings are captured in the SEER and HSPF.

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

Heating Season kWh Savings from efficient fan motor = 168.9[158]

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

$$cooling\ kWh\ savings = \Delta kW\ x\ EFLHcool$$

Where:

ΔkW = .182[159]

EFLHcool = technology and location specific value from tables below

Central AC EFLHcool

Location	EFLHcool
Wilmington, DE	*524* [160]
Baltimore, MD	*542* [161]
Washington, DC	*681*

Air Source Heat Pump EFLHcool

Location	EFLHcool
Wilmington, DE	*719*[162]
Baltimore, MD	*744*[163]
Washington, DC	*935*

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[158] Final_EmPOWER_EY5 HVAC ECM Memo_09-10-15.docx

[159] 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

[160] 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)

[161] 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.

[162] 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)

[163] 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.

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:

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

Where:

ΔkWh ECM 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:

additional annual MMBTU = 168.9/(.85 x 293.1) = .68 MMBTU

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0 [164]

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.[165]

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[164] 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.

[165] 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

Incremental Costs Central Furnace Efficient Fan Motor	
Time of Sale	Retrofit
$98	$287

Measure Life

The measure life is assumed to be 18 years.**Error! Bookmark not defined.**

Operation and Maintenance Impacts

n/a

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labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

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.

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
With Reverse Cycle	<14,000	NA	9.3		10.2
	>= 14,000	NA	8.7		9.6
	<20,000	9.8	NA	10.8	NA
	>=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 v4.0.

Annual Energy Savings Algorithm

ΔkWH = (Hours * BTU/hour * (1/CEERbase - 1/CEERee))/1000

Where:

Hours = Run hours of Window AC unit
= 325 [166]

BTU/hour = Size of rebated unit
When available, the actual size of the rebated unit should be used in the calculation. In the absence of this data, the following default value can be used:
= 8500 [167]

CEERbase = Efficiency of baseline unit in BTUs per Watt-hour
= Actual (see table above)
If average deemed value required use 10.9 [168]

CEERee = Efficiency of ENERGY STAR unit in BTUs per Watt-hour
= Actual
If average deemed value required use 12.0[169] *for an ENERGY STAR unit*

Using deemed values above:

ΔkWH
= (325 * 8500 * (1/10.9 – 1/12)) / 1000
= 23.2 kWh

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[166] 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.

[167] Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[168] Minimum Federal Standard for most common Room AC type – 8000-14,999 capacity range with louvered sides.

[169] Minimum qualifying for ENERGY STAR most common Room AC type – 8000-14,999 capacity range with louvered sides.

Summary Coincident Peak kW Savings Algorithm

$\Delta kW = BTU/hour * (1/CEERbase - 1/CEERee))/1000 * CF$

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)*

= *0.31* [170]

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*

= *0.3*[171]

Using deemed values above:

ΔkW_{SSP}

= (8500 * (1/10.9 – 1/12)) / 1000 * 0.31

= 0.022 kW

ΔkW_{PJM}

= (8500 * (1/10.9 – 1/12)) / 1000 * 0.30

= 0.021 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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

[171] 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).

Incremental Cost[172]

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

Measure Life

The measure life is assumed to be 12 years.[173]

Operation and Maintenance Impacts

n/a

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[172] 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

[173] 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

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 efficiency standards presented below.

Efficiency Level	SEER Rating	EER Rating
Federal Standard	14	11.8[174]
ENERGY STAR	15	12.5

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.

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.

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

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.

Split System Air Conditioner Federal Baselines for Southeast[175]	
Manufacture Date	**SEER**
January 1993 through January 2006	10.0
February 2006 through December 2014	13.0
After January 1 2015	14.0

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

Time of Sale:

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

Early replacement[176]:

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[175] https://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

[176] 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

ΔkWH for remaining life of existing unit:

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

ΔkWH for balance of measure life:

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

Where:

Hours = *Full load cooling hours*

Dependent on location as below:

Location	*Run Hours*
Wilmington, DE	*524* [177]
Baltimore, MD	*542* [178]
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*

= *14* [179]

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

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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).

[177] 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)

[178] 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.

[179] Minimum Federal Standard.

= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11.[180]

SEERee = Seasonal Energy Efficiency Ratio Efficiency of ENERGY STAR unit
= Actual installed

Illustrative example – do not use as default assumption

Time of Sale example: a 3-ton, 14 SEER unit upgraded from lower efficiency to higher, with an equivalent sized unit with SEER rating of 15 in Baltimore:

ΔkWH = 542 x ((36000/14) – (36000/15)) / 1000

= 93 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:

ΔkWH (f remaining life) = 542 x ((36000/11) – (24000/15)) / 1000

= 907 kWh

ΔkWH (through end of life) = 542 x ((36000/14) – (24000/15)) / 1000

= 526 kWh

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[180] 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).

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta \mathrm{kW} = \frac{(BTUHexist\ x\ 1/\ EERbase) - \ (BTUHee\ x\ 1\ /\ EERee)}{1000\ \ x\ CF}$$

Early replacement:

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

$$\Delta \mathrm{kW} = \frac{(BTUHexist\ x\ 1/\ EERexist) - \ (BTUHee\ x\ 1\ /\ EERee)}{1000\ \ x\ CF}$$

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

$$\Delta \mathrm{kW} = \frac{(BTUHexist\ x\ 1/\ EERbase) - \ (BTUHee\ x\ 1\ /\ EERee)}{1000\ \ x\ CF}$$

Where:

EERbase = Energy Efficiency Ratio Efficiency of baseline unit
= 11.8
EERexist = EER Efficiency of existing unit
= Actual EER of unit should be used, if EER is unknown, use 9.9[181]
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)
= 0.69 [182]
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
= 0.66 [183]

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[181] 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 * $SEER^2$) + (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.

[182] 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.

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:

ΔkW_{SSP} = ((36000 x 1/11.8) – (36000 x 1/12.5)) / 1000 x 0.69

= 0.12 kW

ΔkW_{PJM} = ((36000 x 1/11.8) – (36000 x 1/12.5)) / 1000 x 0.66

= 0.11 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:

ΔkW for remaining life of existing unit:

ΔkW_{SSP} = ((36000 x 1/9.9) – (24000 x 1/12.5)) / 1000 x 0.69

= 1.18 kW

ΔkW_{PJM} = ((36000 x 1/9.9) – (24000 x 1/12.5)) / 1000 x 0.66

= 0.1.13 kW

ΔkW for remaining measure life:

ΔkW_{SSP} = ((36000 x 1/11.8) – (24000 x 1/12.5)) / 1000 x 0.69

= 0.78 kW

ΔkW_{PJM} ((36000 x 1/11.8) – (24000 x 1/12.5)) / 1000 x 0.66

= 0.75 kW

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[183] 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

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 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.[184]

The lifecycle NPV incremental costs per ton for this measure are provided below:[185]

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

The measure life is assumed to be 18 years.[186]

Remaining life of existing equipment is assumed to be 6 years[187] unless

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

[185] 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

[186] 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.

otherwise known.

Operation and Maintenance Impacts

n/a

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 efficiency standards presented below:

Efficiency Level	HSPF	SEER Rating	EER Rating[188]
Federal Standard as of 1/1/2015	8.2	14	11.8[189]
ENERGY STAR	8.5	15	12.5

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

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[187] Assumed to be one third of the effective useful life.

[188] HSPF, SEER and EER refer to Heating Seasonal Performance Factor, Seasonal Energy Efficiency Ratio, and Energy Efficiency Ratio, respectively

[189] The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$ 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.

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 andthe 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.

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.

Time of Sale:

$$\Delta \mathrm{kWH} = EFLHcool\ x\ \frac{(\mathrm{BTUHCexist}\ /\ \mathrm{SEERbase}) - (\mathrm{BTUHCee}\ /\ \mathrm{SEERee})}{1000}$$

$$+ EFLHheat\ x\ \frac{(\mathrm{BTUHHexist}\ /\ \mathrm{HSPFbase}) - (\mathrm{BTUHHee}\ /\ \mathrm{HSPFee})}{1000}$$

Early replacement[190]:

ΔkWH for remaining life of existing unit:

$$\Delta \mathrm{kWH} = EFLHcool\ x\ \frac{(\mathrm{BTUHCexist}\ /\ \mathrm{SEERexist}) - (\mathrm{BTUHCee}\ /\ \mathrm{SEERee})}{1000}$$

$$+ EFLHheat\ x\ \frac{(\mathrm{BTUHHexist}\ /\ \mathrm{HSPFexist}) - (\mathrm{BTUHHee}\ /\ \mathrm{HSPFee})}{1000}$$

ΔkWH for remaining measure life:

$$\Delta \mathrm{kWH}$$

$$= EFLHcool\ x\ \frac{(\mathrm{BTUHCexist}\ /\ \mathrm{SEERbasereplace}) - (\mathrm{BTUHCee}\ /\ \mathrm{SEERee})}{1000}$$

$$+ EFLHheat\ x\ \frac{(\mathrm{BTUHHexist}\ /\ \mathrm{HSPFbasereplace}) - (\mathrm{BTUHHee}\ /\ \mathrm{HSPFee})}{1000}$$

Where:

EFLHcool *= Full Load Cooling Hours*

= Dependent on location as below:

Location	*FLHcool*
Wilmington, DE	*719*[191]

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[190] 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).

[191] 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

Baltimore, MD	*744*[192]
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*

SEERbase = *Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump*
= *14*[193]

SEERexist = *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:*

Existing Cooling System	*SEERexist*[194]
Air Source Heat Pump or Central AC	*11*
No central cooling[195]	*Make '1/SEERexist' = 0*

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)

[192] 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.

[193] Minimum federal standard

[194] 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)

[195] 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.

SEERee = *Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump*
= *Actual*

SEERbasereplace = *Baseline Seasonal Energy Efficiency Ratio of same, new equipment type as existing:*

Existing Equipment Type	SEER Rating
ASHP	14
Central AC or no replaced cooling	14

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

Location	FLHheat
Wilmington, DE	*935*[196]
Baltimore, MD	*866*[197]
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*

HSPFbase = *Heating Seasonal Performance Factor of baseline Air Source Heat*
= *8.2*[198]

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[196] 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)

[197] 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.

[198] Minimum Federal Standard

HSPFexist = *Heating System Performance Factor*[199] *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	8.2
Electric Resistance	3.41[200]

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

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[199] 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.

[200] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF

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:

ΔkWH = 744 x ((36,000/14) – (36,000/15))/1,000
+ 866 x ((36,000/7.7) – (36,000/8.5))/1,000

= 509 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 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:

ΔkWH (remaining life) =
744 x ((36,000/11) - (24,000/15))/1,000
+ 866 x ((36,000/3.41) – (24,000/8.5))/1,000

= 7,942 kWh

ΔkWH (through end of life) =
744 x ((36,000/14) - (24,000/15))/1,000
+ 866 x ((36,000/3.41) – (24,000/8.5))/1,000

= 7,420 kWh

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta \mathrm{kW} = \frac{(BTUHCexist\ x\ 1/\ EERbase) - \ (BTUHCee\ x\ 1\ /\ EERee)}{1000\ \ x\ CF}$$

Early replacement:

ΔkW for remaining life of existing unit:

$$\Delta \mathrm{kW} = \frac{(BTUHCexist\ x\ 1/\ EERexist) - \ (BTUHCee\ x\ 1\ /\ EERee)}{1000\ \ x\ CF}$$

ΔkW for remaining measure life:

$$\Delta \mathrm{kW} = \frac{(BTUHCexist\ x\ 1/\ EERbasereplace) - \ (BTUHee\ x\ 1\ /\ EERee)}{1000\ \ x\ CF}$$

Where:

EERbase = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*
= *11.8*[201]

EERexist = 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)[202]

If SEER rating unavailable, use:

Existing Cooling System	EERexist
Air Source Heat Pump or Central AC	9.9
No central cooling[203]	Make '1/EERexist' = 0

EERee = *Energy Efficiency Ratio (EER) of Efficient Air Source Heat Pump*
= *Actual*

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[201] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (14) and equals EER 11.8. 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).

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

[203] 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.

EERbasereplace = *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)*
= *0.69* [204]

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*
= *0.66*[205]

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:

$$\Delta kW_{SSP} = ((36{,}000 \text{ x } 1/11.8) – (24{,}000 \text{ x } 1/12.5))/1{,}000 \text{ x } 0.69$$

$$= 0.78kW$$

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:

ΔkW for remaining life of existing unit (remaining life)

$$\Delta kW_{SSP} = ((36{,}000 \text{ x } 1/9.9) – (24{,}000 \text{ x } 1/12.5))/1{,}000 \text{ x } 0.69$$

$$= 1.18 \text{ kW}$$

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[204] 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.

[205] 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 measure life (through end of life):

ΔkW_{SSP} = ((36,000 x 1/11.8) – (24,000 x 1/12.5))/1,000 x 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:[206]

SEER	Time of Sale	Early Replacement
16	$394	$943
17	$591	$1,140
18	$788	$1,337
19	$985	$1,535
20	$1,182	$1,732
21	$1,379	$1,929

Measure Life

The measure life is assumed to be 18 years[207].

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[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 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

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

Remaining life of existing equipment is assumed to be 6 years[208] unless otherwise known.

Operation and Maintenance Impacts

n/a

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

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 2012 International Energy Conservation Code (IECC 2012) and the 2015 International Energy Conservation Code (IECC 2015) (see table "Baseline Efficiencies by System Type and Unit Capacity" below)[209] or federal standards where more stringent than local energy codes. Note that due to federal standards scheduled to take effect on January 1, 2018, baseline requirements for some equipment classes differ over time.

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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[209] Commercial energy code baseline requirements for Washington, D.C. and Delaware are currently consistent with IECC 2012 (Delaware currently uses ASHRAE 90.1-2010, but the HVAC system requirements are consistent with IECC 2012), whereas Maryland's baseline requirements are consistent with IECC 2015.

Baseline Efficiencies by System Type and Unit Capacity

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards)[210]
Packaged Terminal Air Conditioners[211,212]		
All Capacities	New Construction (Standard Size)[213]	14.0 – (0.300 * Cap/1000) EER
All Capacities	Replacement (Non-Standard Size)	10.9 – (0.213 * Cap/1000) EER
Packaged Terminal Heat Pumps[214,215]		
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

Packaged Terminal Air Conditioners (PTACs)

Time of Sale:

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[210] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.96 (2016).

[211] 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.

[212] "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.

[213] Federal standard as presented for this equipment type is effective January 1, 2017. This standard is consistent with IECC 2015 and ASHRAE 90.1-2013 requirements and is recommended as a consistent regional baseline.

[214] 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.

[215] "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.

For all PTACs, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:
ΔkWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) – (1/EEREE)) * $EFLH_{C.}$

Early Replacement[216]:

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

ΔkWh for remaining life of existing unit (i.e., measure life less the age of the existing equipment):
= (BTU/h/1000) * ((1/EEREXIST) – (1/EEREE)) * $EFLH_C$.

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):
= (BTU/h/1000) * ((1/EERBASE) – (1/EEREE)) * $EFLH_C$.

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:

ΔkWh = ΔkWh_{COOL} + $\Delta kWh_{HEAT.}$
ΔkWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) – (1/EEREE)) * $EFLH_{C.}$
ΔkWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * $EFLH_{H.}$

Early Replacement[217]:

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

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[216] 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.

[217] 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):

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

$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EEREXIST) – (1/EEREE)) * EFLH_{C.}$

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEXIST) – (1/COPEE)) * EFLH_{H}$

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

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

$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) – (1/EEREE)) * EFLH_{C.}$

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * EFLH_{H.}$

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.

SEEREE = SEER of efficient unit.
= Actual Installed.

SEERBASE = SEER of baseline unit.
= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.

SEEREXIST = SEER of the existing unit.
= Actual.

HSPFEE = HSPF of efficient unit.
= Actual Installed.

HSPFBASE = HSPF of baseline unit.
= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.

HSPFEXIST = HSPF of the existing unit.
= Actual.

IEEREE = IEER of efficient unit.
= Actual Installed.

IEERBASE = IEER of baseline unit.
= Based on IECC 2012 or IECC 2015 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 2012 or IECC 2015 for the installed capacity. See table above.
COPEXIST = COP of the existing unit.
= Actual.
EERBASE = EER of baseline unit.
= Based on IECC 2012 or 2015 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).
$EFLH_C$ = Full load cooling hours.[218]
= 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.

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

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[218] 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."

Location	*EFLHc*
Wilmington, DE	*719*[219]
Baltimore, MD	*744*[220]
Washington, DC	*935*

$EFLH_H$ = Full load heating hour value (Table below)

Location	**EFLHh**
Wilmington, DE	*935*[221]
Baltimore, MD	*866*[222]
Washington, DC	*822*

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

ΔkW = $(BTU/h_{COOL}/1000)$ * ((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):

= $(BTU/h_{COOL}/1000)$ * ((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:

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[219] 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)

[220] 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.

[221] 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)

[222] 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.

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.[223]

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.[224]

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.**[225]** Prescribed values vary depending on the current building code, the date of installation, and whether the baseline condition is time of sale or early replacement.[226]

Measure Life

The measure life is assumed to be 15 years.[227]

Operation and Maintenance Impacts

n/a

Operation and Maintenance Impacts

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[223] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

[224] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

[225] 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.

[226] 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

[227] 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.

n/a

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
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

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

Total Annual Savings:

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

<u>Estimate of Cooling savings from reduction in Air Conditioning Load:</u>

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

$$\Delta kWh_{cooling} = ((((DE_{after} - DE_{before})/ DE_{after})) * FLHcool * BTUH) / 1{,}000 / \eta Cool$$

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

FLHcool = Full Load Cooling Hours

= Dependent on location as below:

Location	*FLHcool*

Location	*FLHcool*
Wilmington, DE	*524* [228]
Baltimore, MD	*542* [229]
Washington, DC	*681*

BTUH = *Size of equipment in BTUh (note 1 ton = 12,000BTUh)*
= *Actual*
ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available, use*[230]*:*

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*

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:

$$\Delta kWh_{Cooling} = ((0.90 – 0.80)/0.90) * 524 * 36,000) / 1,000 / 11$$

$$= 191 \text{ kWh}$$

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[228] 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)

[229] 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.

[230] 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.

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

$kWh_{Heating}$ = $(((((DE_{after} – DE_{before})/ DE_{after})) * FLHheat * BTUH) / 1,000,000 / \eta Heat) * 293.1$

Where:

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

Location	**FLHheat**
Wilmington, DE	*935*[231]
Baltimore, MD	*866*[232]
Washington, DC	*822*

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

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available, use*[233]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*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*

Illustrative example – do not use as default assumption
Duct sealing in a 2.5 COP heat pump heated house in Baltimore, MD with the following duct evaluation results:

DE_{before} = 0.80

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[231] 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)

[232] 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.

[233] 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.

DE_{after} = 0.90

Energy Savings:

$\Delta kWh_{Heating}$ = ((((0.90 – 0.80)/0.90) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1

= 406 kWh

Methodology 2: Modified Blower Door Subtraction

Total Annual Savings:

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

Claiming Cooling savings from reduction in Air Conditioning Load:

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

Duct Leakage ($CFM50_{DL}$) = ($CFM50_{Whole\ House}$ – $CFM50_{Envelope\ Only}$) * SCF

Where:

$CFM50_{Whole\ House}$ = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

$CFM50_{Envelope\ Only}$ = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.

SCF = 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.

b. Calculate duct leakage reduction, convert to $CFM25_{DL}$[234] and factor in Supply and Return Loss Factors

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[234] 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).

Duct Leakage Reduction ($\Delta CFM25_{DL}$) = (Pre $CFM50_{DL}$ – Post $CFM50_{DL}$) * 0.64 * (SLF + RLF)

Where :

SLF = Supply Loss Factor
= % leaks sealed located in Supply ducts * 1 [235]
Default = 0.5[236]

RLF = Return Loss Factor
= % leaks sealed located in Return ducts * 0.5[237]
Default = 0.25[238]

c. Calculate Energy Savings:

$\Delta kWh_{cooling}$ = (($\Delta CFM25_{DL}$)/ (Capacity * 400)) * FLHcool * BTUH) / 1000 / ηCool

Where:

$\Delta CFM25_{DL}$ = 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*
Wilmington, DE	*524* [239]

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[235] 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

[236] Assumes 50% of leaks are in supply ducts.

[237] 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

[238] Assumes 50% of leaks are in return ducts.

Baltimore, MD	*542* [240]
Washington, DC	*681*

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

ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available, use*[241]*:*

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*

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:

$\text{CFM50}_{\text{Whole House}}$ = 4,800 CFM50
$\text{CFM50}_{\text{Envelope Only}}$ = 4,500 CFM50
House to duct pressure = 45 Pascals
= 1.29 SCF (Energy Conservatory look up table)

After:

$\text{CFM50}_{\text{Whole House}}$ = 4,600 CFM50

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[239] 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)

[240] 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.

[241] 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.

$CFM50_{Envelope\ Only}$ = 4,500 CFM50
House to duct pressure = 43 Pascals
= 1.39 SCF (Energy Conservatory look up table)

Duct Leakage at CFM50:

$CFM50_{DL\ before}$ = (4,800 – 4,500) * 1.29
= 387 CFM50

$CFM50_{DL\ after}$ = (4,600 – 4,500) * 1.39
= 139 CFM50

Duct Leakage reduction at CFM25:

$\Delta CFM25_{DL}$ = (387 – 139) * 0.64 * (0.5 + 0.25)
= 119 CFM25

Energy Savings:

$\Delta kWh_{Cooling}$ = ((119 / (3 * 400)) * 524 * 36,000) / 1,000 / 11

= 170 kWh

<u>Claiming Heating savings for homes with electric heat (Heat Pump):</u>

$\Delta kWh_{Heating}$ = $(((\Delta CFM25_{DL} / (Capacity * 400)) * FLHheat * BTUH) / 1{,}000{,}000 / \eta Heat) * 293.1$

Where:

$\Delta CFM25_{DL}$ = 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:

Location	FLHheat
Wilmington, DE	*935*[242]

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[242] 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

Baltimore, MD	*866*[243]
Washington, DC	*822*

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

ηHeat = Efficiency in COP of Heating equipment
= actual. If not available, use[244]*:*

System Type	***Age of Equipment***	***HSPF Estimate***	***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*

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:

$\Delta kWh_{Heating}$ = (((119 / (3 * 400)) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1

= 362 kWh

Methodology 3: Duct Blaster Testing

Total Annual Savings:

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

<u>Claiming Cooling savings from reduction in Air Conditioning Load:</u>

(2061) to Baltimore MD (2172) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

[243] 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.

[244] 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.

$$\Delta kWh_{cooling} = (((Pre\_CFM25 - Post\_CFM25)/ (Capacity * 400)) * FLHcool * BTUH) / 1000 / \eta Cool$$

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.

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:

Pre_CFM25 = 220 CFM25
Post_CFM25 = 80 CFM25

$$\Delta kWh_{Cooling} = (((220 - 80) / (3 * 400)) * 524 * 36,000) / 1,000 / 11$$

$$= 200 \text{ kWh}$$

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

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

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:

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

$$= 426 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh_{Cooling} / FLHcool * CF$$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [245]

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*
= *0.66* [246]

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

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

$$\Delta MMBTUfossil\ fuel = ((((DE_{after} – DE_{before})/ DE_{after})) * FLHheat * BTUH) / 1{,}000{,}000 / \eta Heat$$

Where:

DE_{after} = *Distribution Efficiency after duct sealing*
DE_{before} = *Distribution Efficiency before duct sealing*
FLHheat = *Full Load Heating Hours*
= *620*[247]
BTUH = *Capacity of Heating System*
= *Actual*
η*Heat* = *Efficiency of Heating equipment*

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[245] 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.

[246] 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.

[247] 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.

= Actual[248]*. If not available, use 84%*[249]*.*

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:
ΔMMBTU = ((0.90 – 0.80)/0.90) * 620 * 100,000) / 1,000,000 / 0.80

= 8.6 MMBTU

Methodology 2: Modified Blower Door Subtraction

$$\Delta MMBTU = (((\Delta CFM25_{DL} / (BTUH * 0.0126)) * FLHheat * BTUH) / 1,000,000 / \eta Heat$$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25
BTUH = Capacity of Heating System (BTUh)
= Actual
0.0126 = Conversion of Capacity to CFM (0.0126CFM / BTUh)[250]
FLHheat = Full Load Heating Hours
= 620[251]

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

[249] 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%.

[250] 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.

[251] 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,

$\eta Heat$ = Efficiency of Heating equipment
= Actual[252]. If not available, use 84%[253].

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:

$$\Delta MMBTU = (((119 / (100{,}000 * 0.0126)) * 620 * 100{,}000) / 1{,}000{,}000 / 0.80$$

$$= 7.3 \text{ MMBTU}$$

Methodology 3: Duct Blaster Testing

$$\Delta MMBTU = (((Pre\_CFM25 – Post\_CFM25/ (BTUH * 0.0126)) * FLHheat * BTUH) / 1{,}000{,}000 / \eta Heat$$

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:

$$\Delta MMBTU = (((220 - 80 / (100{,}000 * 0.0126)) * 620 * 100{,}000) / 1{,}000{,}000 / 0.80$$

$$= 8.6 \text{ MMBTU}$$

Annual Water Savings Algorithm

n/a

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technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLHheat assumption.

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

[253] 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%.

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 years[254].

Operation and Maintenance Impacts

n/a

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[254] 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

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, 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.

The baseline condition in time of sale / new construction is a standard-efficiency ductless unit meeting the following efficiency standards:

Year	SEER	EER	HSPF
2015	14	8.5[255]	8.2

Definition of Efficient Condition

The efficient condition is an ENERGY STAR ductless heat pump exceeding all of the following efficiency standards; 15 SEER, 12.5 EER, 8.5 HSPF.

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[255] Typical EER for units with a SEER of 14 from the AHRI database.

Annual Energy Savings Algorithm

If displacing/replacing electric heat:

$$\Delta kWh_{total} = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = CoolingLoadDHP \text{ x } (1/SEER_{base} \text{ x } (1 + \Delta DL_{impr} \text{ x } DL_{cool}) - 1/SEER_{ee})$$

$$\Delta kWh_{heat} = HeatLoadElectricDHP \text{ x } (3.412/HSPF_{base} \text{ x } (1 + \Delta DL_{impr} \text{ x } DL_{heat}) - 3.412/HSPF_{ee})$$

If displacing/replacing gas heat:

$$\Delta kWh_{total} = \Delta kWh_{cool} - Total\_kWh_{heat}$$

$$\Delta kWh_{cool} = CoolingLoadDHP \text{ x } (1/SEER_{base} \text{ x } (1 + \Delta DL_{impr} \text{ x } DL_{cool}) - 1/SEER_{ee})$$

$$Total\_kWh_{heat} = (HeatLoadGasDHP \text{ x } 293.1 \text{ x } 3.412 / HSPFee)$$

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)

Early Replacement = Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11[256] *for Central AC or 10.7 for Room AC*[257]*. If no cooling exists, assume 14.0.*

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[256] 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.

[257] Estimated by converting the minimum standard for Room A/Cs before 2005 (9.7) by 1.1 to adjust for SEER.

Time of Sale / New Construction = 14.0[258]

SEERee = *Efficiency i n SEER of efficient ductless heat pump*

= *Actual (kBTU cooling/ kWh consumed)*

HeatLoadElectricDHP

= *Heating load (kWh) that the DHP will now provide*

= *Actual*[259]

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*

HSPFbase = *Heating Seasonal Performance Factor of existing system or baseline ductless heat pump for new construction*

Early Replacement = *Use actual HSPF rating where it is possible to measure or reasonably estimate.*

If unknown assume 3.412[260] *for resistance heat,* 7.15[261] for ASHP.

Time of Sale / New Construction = *8.2* [262]

HSPFee = *Heating Seasonal Performance Factor of ENERGY STAR ductless heat pump*[263]

= *Actual*

HeatLoadGasDHP = *Heating load (MMBTU) that the DHP will now provide*

= *Actual*[264]

293.1 = *Converts MMBTU to kWh*

AFUEexist = *Efficiency of existing furnace or boiler*

= *Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 84%*[265].

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[258] Minimum Federal Standard

[259] For example with a Manual-J calculation or similar modeling.

[260] Assume COP of 1.0 converted to HSPF by multiplying by 3.412.

[261] 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.

[262] Minimum Federal Standard

[263] 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.

[264] For example with a Manual-J calculation or similar modeling.

[265] 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

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/EERbase x (1 + ΔDL_{impr} * DL_{cool}) - 1/EERee))/1,000 x CF

Where:

$BTUH_{Cool}$ = *Cooling capacity in BTUs per hour (tons x 12,000BTU/hr per ton)*
= Actual

EERbase = *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 9.9[266] *for Central AC or 9.7 for Room AC*[267].
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 = *8.5*[268]

EERee = *Energy Efficiency Ratio (EER) of Efficient ductless heat pump*
= Actual.

DL_{cool} = *1 if duct leakage applies based on baseline cooling equipment (0 otherwise)*

ΔDL_{impr} = Duct loss improvement factor, 0.15

CF = *Coincidence Factor for measure. Assumptions for both Central AC and Room AC are provided below. The*

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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%.

[266] 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: $(-0.02 * SEER^2) + (1.12 * SEER)$. 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.

[267] 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."

[268] Typical EER for DMSHP units with a SEER of 14 from the AHRI database

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.

$CF_{SSP\ Room\ AC}$ = *Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [269]

$CF_{PJM\ Room\ AC}$ = *PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[270]

$CF_{SSP\ Central\ AC}$ = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [271]

$CF_{PJM\ Central\ AC}$ = *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* [272]

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.

$$\Delta MMBTU = HeatLoadGasReplaced / AFUEexist * (1 + \Delta DL_{impr} * DL_{heat})$$

Where:

HeatLoadGasReplaced
= *Heating load (MMBTU) that the DHP will now provide in place of gas unit*

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

[270] 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).

[271] 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.

[272] 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.

= *Actual*[273]

AFUEexist = *Efficiency of existing heating system*

= *Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 80%*[274] *for early retirement, or 80% for replace on burnouts*[275].

DL_{heat} = *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:[276]

Unit Size (tons)	Time of Sale	Early Replacement
1	$267	$915
1.5	$400	$1,252
2	$533	$1,588
2.5	$667	$1,925
3	$800	$ 2,262

Measure Life

The measure life is assumed to be 18 years[277]. 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.

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[273] For example with a Manual-J calculation or similar modeling.

[274] 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%.

[275] This has been estimated assuming that the average efficiency of existing heating systems is likely to include newer more efficient systems.

[276] 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

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.

ΔkWH = (CoolingLoadDHP x (1/SEERbase - 1/SEERee)) +
(HeatLoadElectricDRP x (3.412/HSPFbase – 3.412/HSPFee))
= (2000 x (0 – 1/20)) + (5000 x (3.412/3.412 – 3.412/12))
= 3,478 kWh

ΔkW_{SSP} = $BTUH_{Cool}$ x (1/EERbase - 1/EERee))/1,000 x CF
= (18,000 x (0 – 1/14)) / 1000) x 0.31
= - 0.40kW

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.

ΔkWH = (CoolingLoadDHP x (1/SEERbase - 1/SEERee)) -
(HeatLoadGasDHP x 293.1 x 0.85 x (3.412/HSPFee))
= (4000 x (1/11 – 1/18)) - (40 x 293.3 x 0.85 x (3.412/11))
= -2,952 kWh (i.e. this results in an increase in electric consumption)

ΔkW_{SSP} = ($BTUH_{Cool}$ x (1/EERbase - 1/EERee))/1,000 x CF
= (30,000 x (1/9.96 – 1/13.5)) / 1000 x 0.31
= 0.24 kW (in the summer you see demand savings)

ΔMMBTU = HeatLoadGasReplaced / AFUEexist
= 40 / 0.80
= 50 MMBTU

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

ΔkWH = (CoolingLoadDHP x (1/SEERbase - 1/SEERee)) +
(HeatLoadElectricDHP x (3.412/HSPFbase – 3.412/HSPFee))
= (6000 x (1/14 – 1/18)) + (12,000 x (3.412/7.7– 3.412/11))

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[277] 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.

$= 1{,}634 kWh$

$\Delta kW_{SSP} = (BTUH_{Cool} \times (1/EERbase - 1/EERee))/1{,}000 \times CF$

$= (36{,}000 \times (1/11.8 – 1/13.5)) / 1000 \times 0.31$

$= 0.12\ kW$

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 September 2012, the Federal baseline is 82% 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

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (EFLHheat * BTUh * ((AFUEee/AFUEbase) - 1)) /1,000,000$$

Where:

EFLHheat = Equivalent Full Load Heating Hours

Location	*EFLH*
Wilmington, DE	*848*[278]
Baltimore, MD	*620*[279]
Washington, DC	*528*[280]

BTUH = *Input Capacity of Boiler*
= *Actual*
AFUEbase = *Efficiency in AFUE of baseline boiler*
= *82%*
AFUEee = *Efficiency in AFUE of efficient boiler*
= *Actual*

Illustrative example – do not use as default assumption
The purchase and installation of a 100,000 BTUh input capacity, 90% AFUE boiler in Maryland:

ΔMMBTU = (620 * 100,000 * ((0.9/0.82) – 1)) /1,000,000

= 6.0 MMBTU

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental costs for this measure are provided below:[281]

Efficiency of Boiler (AFUE)	Incremental Cost
90%	$469

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[278] 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

[279] 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.

[280] 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.

[281] 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

92%	$513
95%	$643
98%	$789

Measure Life

The measure life is assumed to be 18 years[282] .

Operation and Maintenance Impacts

n/a

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[282] 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.

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 weatherized[283].

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified gas-fired condensing furnace with an AFUE rating ≥ 90%.

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

$$\Delta MMBTU = (EFLHheat * BTUh * ((AFUEee/AFUEbase) - 1) /1{,}000{,}000$$

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[283] Current federal minimum. See http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0102-0008.

Where:

EFLHheat *= Equivalent Full Load Heating Hours*

Location	*EFLH*
Wilmington, DE	*848*[284]
Baltimore, MD	*620*[285]
Washington, DC	*528*[286]

BTUH *= Input Capacity of Furnace*
= Actual

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.[287]

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[284] 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

[285] 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.

[286] 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.

[287] 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-

Efficiency of Furnace (AFUE)	Incremental Cost
90%	$392
92%	$429
95%	$537
98%	$659

Measure Life

The measure life is assumed to be 18 years[288].

Operation and Maintenance Impacts

n/a

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.

[288] 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.

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 certification[289] and/or has the following product requirements[290]:

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 ≤ ± 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

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[289] ENERGY STAR's qualified products list for smart thermostats: https://data.energystar.gov/Active-Specifications/ENERGY-STAR-Certified-Smart-Thermostats/7p2p-wkbf

[290] 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

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

As smart thermostats are control technologies, when possible, heating and cooling savings should be calculated based on data from installed thermostats.[291] 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:

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

$\Delta kWh_{heating} = Elec\_Heating\_Saving\_\% \times Elec\_Heating\_kWh$

$\Delta kWh_{cool} = Cooling\_Saving\_\% \times Cooling\_kWh$

$\Delta MMBTU = Fuel\_Heating\_Saving\_\% \times Fuel\_Heating\_MMBTU \times QUANT \times QUANTafh$

Where:

Elec_Heating_Saving_% = 6%

Cooling_Saving_% = 7%

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[291] 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.

Fuel_Heating_Saving_% = 6%[292]
Elec_Heating_kWh = actual seasonal electric heat kWh consumption
Cooling_kWh = actual seasonal cooling kWh consumption
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);
= .727[293] (if QUANT >1)

Where actual heating or cooling energy consumption is not known, use the following algorithms:

Cooling Savings:

$$\Delta\text{kWh} = \frac{\text{CCAP}}{\text{SEER}} \text{ x EFLHc x Cooling\_Saving\_\%}$$

Electric Heat Savings:

$$\Delta\text{kWh} = \frac{\text{HCAPelec}}{\text{HSPF}} \text{ x EFLHh x Elec\_Heating\_Saving\_\%}$$

Fossil heat Savings:

$$\Delta\text{MMBTU} = \frac{\text{HCAPfuel}}{\text{AFUE}} \text{ x EFLHh x Fuel\_Heating\_Saving}_{\%} \text{ x QUANT x QUANTafh}$$

Where:

CCAP = Cooling capacity of existing AC unit, in kBTU/hr.
$\text{HCAP}_{\text{elec}}$ = Heating capacity of existing electric heat unit, in kBTU/hr.

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[292] Smart thermostat deemed savings percentages drawn from 2017 literature survey performed by Joe Loper of Itron, see Smart_Thermostat_Literature_Summary_WORKING022417.xls

[293] 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

$HCAP_{fuel}$ = 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

QUANTafh = adjustment factor for installed measure quantity with heating system
= 1.0 (if QUANT = 1);
= .727[294] (if QUANT >1)

EFLHheat for Air Source Heat Pump

Location	*EFLHheat*
Wilmington, DE	*935*[295]
Baltimore, MD	*866*[296]
Washington, DC	*822*

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[294] 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. 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

[295] 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)

[296] 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.

EFLHheat Gas Furnace and Boiler; Ground Source Heat Pump

Location	*EFLH*
Wilmington, DE	*848*[297]
Baltimore, MD	*620*[298]
Washington, DC	*528*[299]

EFLHcool for Air Source Heat Pump, split system

Location	*EHLHcool*
Wilmington, DE	*719*[300]
Baltimore, MD	*744*[301]
Washington, DC	*935*

EFLHcool for Central AC, ducted split system; GSHP

Location	*Run Hours*
Wilmington, DE	*524* [302]
Baltimore, MD	*542* [303]

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[297] 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

[298] 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.

[299] 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.

[300] 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)

[301] 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.

[302] 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)

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						
	HVAC Replacement?	**Unknown**	**HVAC Unit Not Replaced**		**HVAC Unit Replaced**	
State	**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
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 $154[304] and the incremental cost for a retrofit

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[303] 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.

[304] 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

replacement is assumed to be $208.[305] If thermostats are professionally installed, $50 for labor should be added to the assumed incremental cost.

Measure Life

The measure life is assumed to be 7.5 years.[306]

Operation and Maintenance Impacts

n/a

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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.

[305] 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.

[306] 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

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 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 CEER[307]).

Definition of Efficient Condition

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 12.0[308]).

Annual Energy Savings Algorithm

Savings for remaining life of existing unit (1st 3 years)

ΔkWh = (Hours * BTUH * (1/EERexist - 1/CEERee))/1,000

Savings for remaining measure life (next 9 years)

ΔkWh = (Hours * BTUH * (1/CEERbase - 1/CEERee))/1,000

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[307] Minimum Federal Standard for most common Room AC type – 8000-14,999 capacity range with louvered sides.

[308] Minimum qualifying for ENERGY STAR most common Room AC type – 8000-14,999 capacity range with louvered sides.

Where:

Hours = Run hours of Window AC unit
= 325[309]
BTUh = Capacity of replaced unit
= Actual or 8,500 if unknown[310]
EERexist = Efficiency of existing unit in BTUs per Watt-hour
= 9.8[311]
CEERbase = Efficiency of baseline unit in BTUs per Watt-hour
= 10.9[312]
CEERee = Efficiency of ENERGY STAR unit in BTUs per Watt-hour
= Actual or CEER 12 if unknown

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)

$$\Delta kWh = (325 * 8{,}500 * (1/9.8 - 1/12)) / 1{,}000$$

$$= 52\ kWh$$

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (325 * 8{,}500 * (1/10.9 - 1/12)) / 1{,}000$$

$$= 23\ kWh$$

Summer Coincident Peak kW Savings Algorithm

Savings for remaining life of existing unit (1st 3 years)

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[309] 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.

[310] Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

[311] 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.

[312] Minimum Federal Standard for capacity range.

$\Delta kW = ((BTUH * (1/EERexist - 1/CEERee))/1000) * CF$

Savings for remaining measure life (next 9 years)

$\Delta kW = ((BTUH * (1/CEERbase - 1/CEERee))/1000) * CF$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [313]

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*
= *0.3*[314]

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 12.0.

Savings for remaining life of existing unit (1st 3 years)

ΔkW_{SSP} = ((8,500 * (1/9.8 – 1/12)) / 1,000) * 0.31

= 0.0493 kW

Savings for remaining measure life (next 9 years)

ΔkW_{SSP} = ((8,500 * (1/10.9 – 1/12)) / 1,000) * 0.31

= 0.0222 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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

[314] 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).

Incremental Cost

The lifecycle NPV incremental cost for this early replacement measure is provided below.[315]

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
	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 years[316]. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced[317].

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:

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[315] 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

[316] 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.

[317] Based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year

$NPV_{deferred\ replacement\ cost}$ = (Actual Cost of ENERGY STAR unit - \$240[318]) * 86%[319].

Note that this is a lifecycle cost savings (i.e. a negative cost).

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[318] Itron Inremental Cost Review 2017

[319] With a discount rate of 5%, the net present value of replacement in year 4 would be 0.95^3 = 0.86.

Room Air Conditioner, Early Retirement / Recycling

Unique Measure Code: RS_HV_ERET_RA/C_0414
Effective Date: June 2014
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. 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

$$\Delta kWh = ((Hours * BTUH * (1/EERexist))/1{,}000) - (\%replaced * ((Hours * BTUH * (1/EERnewbase))/ 1{,}000)$$

Where:

Hours = Run hours of Window AC unit
= 325 [320]
BTU/hour = Capacity of replaced unit
= Actual or 8,500 if unknown [321]

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[320] 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.

[321] Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

EERexist = *Efficiency of existing unit in BTUs per Watt-hour*
= *Actual or 9.8 if unknown* [322]
%replaced = Percentage of units dropped off that are replaced in the home
= 76% [323]
CEERnewbase = *Efficiency of new baseline unit in BTUs per Watt-hour*
= 10.9[324]

Illustrative example – do not use as default assumption
The turn in of an 8,500 BTUh, 7.7 EER unit:

ΔkWh = ((325 * 8,500 * (1/9.8))/1,000) -
(0.76 * ((325 * 8,500 * (1/10.9))/1,000)

= 89 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = [(BTUH * (1/EERexist)/1,000) -
(%replaced * BTUH * (1/CEERnewbase)/1,000)] * CF

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [325]

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[322] 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.

[323] 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.

[324] 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.

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

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*
= 0.3[326]

Illustrative example – do not use as default assumption
The turn in of an 8500 BTUh, 9.8 EER unit:

$$\Delta kW_{SSP} = ((8{,}500 * (1/9.8))/1{,}000) * 0.31 - (0.76 * ((8{,}500 * (1/10.9))/1{,}000)) * 0.31$$

$$= 0.09 \text{ kW}$$

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.[327]

Measure Life

The measure life is assumed to be 3 years[328].

Operation and Maintenance Impacts

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

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[326] 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).

[327] 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.

[328] 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

have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $158[329].

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[329] 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)

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

$\Delta MMBTU = (((1/R_{exist}) – (1/R_{new})) * FLH\_heat * C_{exist} * L * \Delta T) / \eta Boiler /1,000,000$

Where:

R_{exist} = *Pipe heat loss coefficient of uninsulated pipe* $[(hr\text{-}°F\text{-}ft^2)/BTU]$
= *0.5*[330]

R_{new} = *Pipe heat loss coefficient of insulated pipe* $[(hr\text{-}°F\text{-}ft^2)/BTU]$
= *Actual (0.5 + R value of insulation)*

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[330] 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.

EFLH_heat = Equivalent Full load hours of heating

Location	EFLH
Wilmington, DE	848 [331]
Baltimore, MD	620 [332]
Washington, DC	528 [333]

L = Length of boiler pipe in unconditioned space covered by pipe wrap (ft)
= Actual

C_{exist} *= Circumference of bare pipe (ft) (Diameter (in) * π/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) [334]

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

ηBoiler = Efficiency of boiler
= 0.84 [335]

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[331] 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

[332] 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.

[333] 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.

[334] 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).

[335] Assumed efficiency of existing boilers.

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:

$$\Delta MMBTU = (((1/R_{exist}) - (1/R_{new})) * FLH\_heat * C_{exist} * L * \Delta T) / \eta Boiler /1{,}000{,}000$$

$$= (((1/0.5) - (1/3.5)) * 848 * 0.196 * 15 * 120) / 0.85 / 1{,}000{,}000$$

$$= 0.63 \text{ MMBTU}$$

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.[336]

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 15 years[337].

Operation and Maintenance Impacts

N/A

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[336] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

[337] 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.

Boiler Reset Controls

Unique Measure Code: RS_HV_RF_BLRRES_0415
Effective Date:
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 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

$$\Delta MMBTU = (\text{Savings }\%) * (EFLHheat * BTUh) / 1{,}000{,}000$$

Where:

Savings % = *Estimated percent reduction in heating load due to boiler reset controls being installed*
= *5%*[338]

EFLHheat = *Equivalent Full Load Heating Hours*

Location	*EFLH*
Wilmington, DE	*848*[339]
Baltimore, MD	*620*[340]
Washington, DC	*528*[341]

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.

$$\Delta MMBTU = 0.05 * (620 * 80,000)/1,000,000$$

$$= 2.48 \text{ MMBTU}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The cost of this measure is $612[342]

Measure Life

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[338] 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/

[339] 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

[340] 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.

[341] 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.

[342] Nexant. Questar DSM Market Characterization Report. August 9, 2006.

The life of this measure is 15 years[343]

Operation and Maintenance Impacts

n/a

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[343] New York State TRM v4.0, April 2016

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[344]	16	3.6

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:

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[344] 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.

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[345] 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 follows[346]:

For <=55 gallons: EF = 0.96 – (0.0003 x rated volume in gallons)
For >55 gallons: EF = 2.057 – (0.00113 x rated volume in gallons)

If size is unknown, assume 50 gallons; 0.945 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 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 x rated volume in gallons)[347]
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 x rated volume in gallons)[348].
If size is unknown, assume 40 gallons; 0.594 EF

If DHW fuel is unknown, assume electric DHW provided above.

Definition of Efficient Condition

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[345] The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$ Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

[346] Minimum Federal Standard as of 4/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

[347] 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

[348] 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

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

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]
= [(FLHcool x BTUc x (1/SEER$_{base}$– (1/EER$_{PL}$)/1000] + [FLHheat x BTUh x (1/HSPF$_{base}$ – (1/(COP$_{PL}$ x 3.412)))/1000] + [ElecDHW x %DHWDisplaced x (((1/EF$_{ELEC}$) x GPD x Household x 365.25 x γWater x (T$_{OUT}$ – T$_{IN}$) x 1.0) / 3412)]

Where:

FLHcool = *Full load cooling hours*
Dependent on location as below:

Location	*Run Hours*
Wilmington, DE	*524* [349]
Baltimore, MD	*542* [350]
Washington, DC	*681*

BTUc = Cooling capacity in BTUs per hour (tons x 12,000BTU/hr)
BTU$_H$ = Heating capacity in BTUs per hour (tons x 12,000BTU/hr)
SEERbase = *SEER Efficiency of new replacement baseline unit*
= *14*[351]
EER$_{FL}$ = *Full Load EER Efficiency of efficient GSHP unit*[352]
= *Actual installed*
FLHheat = *Full load heating hours*

Location	*EFLH*
Wilmington, DE	*848*[353]

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[349] 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)

[350] 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.

[351] 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

[352] As per Navigant-Cadmus 2017-2018 Deemed Savings Exception memo.

Baltimore, MD	*620*[354]
Washington, DC	*528*[355]

$HSPF_{base}$ =Heating System Performance Factor of new replacement baseline heating system (kBTU/kWh)
=8.2 [356]

COP_{FL} = Full Load Coefficient of Performance of efficient unit[357]
= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

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%[358]
= 0% if no desuperheater installed

EF_{ELEC} = Energy Factor (efficiency) of electric water heater
For new construction assume federal standard[359]*:*
For <=55 gallons: 0.96 – (0.0003 x rated volume in gallons)
For >55 gallons: 2.057 – (0.00113 x rated volume in gallons)
If size is unknown, assume 50 gallon; 0.945 EF.

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[353] 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

[354] 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.

[355] 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.

[356] 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

[357] As per Navigant-Cadmus 2017-2018 Deemed Savings Exception memo

[358] Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 * 2/3 = 44%). Based on input from Doug Dougherty, Geothermal Exchange Organization.

[359] Minimum Federal Standard as of 4/1/2015; http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

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 x rated volume in gallons)[360]
If size is unknown, assume 50 gallon; 0.864 EF

GPD = Gallons Per Day of hot water use per person
= 45.5 gallons hot water per day per household/2.59 people per household[361]
= 17.6

Household = Average number of people per household

= 2.53 [362]
365.25 = Days per year
γWater = 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 [363]
1.0 = Heat Capacity of water (1 BTU/lbx°F)
3412 = Conversion from BTU to kWh

Illustrative Example – do not use as default assumption

New Construction:

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[360] 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

[361] Based upon email message from Maureen Hodgins, Research Manager for Water Research Foundation, on August 26, 2014.

[362] 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

[363] 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.

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:

ΔkWh = [(FLHcool x BTUc x (1/$SEER_{base}$ – (1/EER_{PL})/1000] + [(FLHheat x BTUh x (1/HSPFbase – (1/COP_{PL} x 3.412)))/1000] + [ElecDHW x %DHWDisplaced x (((1/ $EF_{ELEC\ EXIST}$) x GPD x Household x 365.25 x γWater x (T_{OUT} – T_{IN}) x 1.0) / 3412)]

ΔkWh = [(542 x 36,000 x (1/14 – 1/19)) / 1000] + [(620 x 36,000 x (1/8.2 – 1/ (4.4x3.412))) / 1000] + [1 x 0.44 x (((1/0.945) x 17.6 x 2.53 x 365.25 x 8.33 x (125-60.9) x 1)/3412)]

= 367 + 1235 + 1185

= 2787 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (BTUc x (1/EERbase - 1/EER_{FL}))/1000) x CF

Where:

EERbase = *EER Efficiency of new replacement unit*
= *11.8*[364]

EER_{FL} = *Full Load EER Efficiency of ENERGY STAR GSHP unit* [365]
= *Actual*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [366]

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*
= *0.66* [367]

Illustrative Example– do not use as default assumption

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

[365] 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.

[366] 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.

[367] 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.

New Construction or Time of Sale:
For example, a 3-ton unit with Full Load EER rating of 19:

ΔkW_{SSP} = ((36,000 x (1/11.8 – 1/19))/1000) x 0.69
= 0.80 kW

ΔkW_{PJM} = ((36,000 x (1/11 – 1/19))/1000) x 0.66
= 0.76 kW

Annual Fossil Fuel Savings Algorithm

Savings for Time of Sale where existing hot water heater is gas fired:

ΔMMBTU = [DHW Savings]
= [(1 – ElecDHW) x %DHWDisplaced x (1/ $EF_{GAS\ BASE}$ x GPD x Household x 365.25 x γWater x (T_{OUT} – T_{IN}) x 1.0) / 1,000,000)

Where:

$EF_{GAS\ EXIST}$ = 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 x rated volume in gallons)[368]*.*
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

ΔMMBTU = [(1 – ElecDHW) x %DHWDisplaced x (1/ $EF_{GAS\ BASE}$ x GPD x Household x 365.25 x γWater x (T_{OUT} – T_{IN}) x 1.0) / 1,000,000)]
= [(1 – 0) x 0.44 x (((1/0.594) x 17.6 x 2.53 x 365.25 x 8.33 x (125 - 60.9) x 1)/1,000,000)]
= 6.4 MMBTU

Annual Water Savings Algorithm

n/a

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[368] 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

Incremental Cost

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 ton[369]), minus the assumed installed cost of the baseline equipment ($838 per ton for ASHP[370]).

Measure Life

The expected measure life is assumed to be 20 years[371].

Operation and Maintenance Impacts

N/A

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[369] Based on data provided to VEIC in ‘Results of Home geothermal and air source heat pump rebate incentives documented by Illinois electric cooperatives’.

[370] 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.

[371] 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.

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 3.1[372]) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[373].

Definition of Efficient Condition

New efficient (average CFM/watt of 8.3[374]) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate (20 CFM) indicated by ASHRAE 62.2[375]

Annual Energy Savings Algorithm

$$\Delta kWh = (CFM * (1/\eta Baseline - 1/\eta Efficient)/1000) * Hours$$

Where:

CFM = *Nominal Capacity of the exhaust fan*
= *20 CFM*[376]

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[372] 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.

[373] On/off cycling controls may be required of baseline fans larger than 50CFM.

[374] 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.

[375] Bi-level controls may be used by efficient fans larger than 50 CFM

ηBaseline = Average efficacy for baseline fan
= 3.1 CFM/Watt[377]
ηEffcient = Average efficacy for efficient fan
= 8.3 CFM/Watt[378]
Hours = assumed annual run hours,
= 8760 for continuous ventilation.

$$\Delta kWh = (20 * (1/3.1 - 1/8.3)/1000) * 8760$$
$$= 35.4 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (CFM * (1/\eta Baseline - 1/\eta Efficient)/1000) * CF$$

Where:

CF = Summer Peak Coincidence Factor
= 1.0 (continuous operation)

Other variables as defined above

$$\Delta kW = (20 * (1/3.1 - 1/8.3)/1000) * 1.0$$
$$= 0.0040 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[376] 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.

[377] 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.

[378] 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.

For this time of sale measure, the incremental cost per installed fan is $43.50[379].

Measure Life

The expected measure life is assumed to be 19 years[380].

Operation and Maintenance Impacts

N/A

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[379] VEIC analysis using cost data collected from wholesale vendor; http://www.westsidewholesale.com/.

[380] 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.

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 designs[381].

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

$$\Delta kWh = \Delta kWh_{fan} + \Delta kWh_{Light}$$

$$\Delta kWh_{fan} = [Days * FanHours * ((\%Low_{base} * WattsLow_{base}) + (\%Med_{base} * WattsMed_{base}) + (\%High_{base} * WattsHigh_{base}))/1000] - [Days * FanHours * ((\%Low_{ES} * WattsLow_{ES}) + (\%Med_{ES} * WattsMed_{ES}) + (\%High_{ES} * WattsHigh_{ES}))/1000]$$

$$\Delta kWh_{light} = ((WattsBase - WattsEE)/1000) * ISR * HOURS * (WHFe_{Heat} + (WHFe_{Cool} – 1))$$

See ENERGY STAR Integrated Screw Based SSL screw-in measure (assume ISR = 1.0)

Where[382]*:*

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%

$WattsMed_{base}$ *= 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

%LowES = 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*
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
WattsBase = 3 x 43 = 129 W

WattsEE = 1 x 42 = 42 W

Deemed savings if using defaults provided above:

ΔkWh_{fan} = [365.25 * 3 * ((0.4 * 15) + (0.4 * 34)+(0.2 * 67))/1000] – [365.25 * 3 *((0.4 * 6)+(0.4 * 23)+(0.2 * 56))/1000]
= 36.2 – 25.0
= 11.2 kWh

ΔkWh_{light} =((129 – 42)/1000) * 1.0 * 898 * (0.899 + (1.09-1))
= 77.3 kWh

ΔkWh = 11.2 + 77.3

= 88.5 kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kW_{Fan} + \Delta kW_{light}$

$\Delta kW_{Fan} = ((WattsHigh_{base} - WattsHigh_{ES})/1000) * CFfan$

ΔkW_{Light} = ((WattsBase - WattsEE) /1000) * ISR * WHFd * CFlight

See General Purpose CFL Screw Based, Residential measure (assume ISR = 1.0)

Where:

$CFfan_{SSP}$ = *Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= *0.31* [383]

$CFfan_{PJM}$ = *PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[384]

CFlight = 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[385]
	PJM CF	0.084[386]

Deemed savings if using defaults provided above:

$\Delta kW_{fan\ ssp}$ = ((67-56)/1000) * 0.31
=0.0034 kW

$\Delta kW_{light\ ssp}$ =((129 – 42)/1000) * 1.0 * 1.17 * 0.082
= 0.0083 kW

ΔkW_{ssp} = 0.0034 + 0.0083
= 0.012 kW

$\Delta kW_{fan\ pjm}$ = ((67-56)/1000) * 0.3
=0.0033 kW

$\Delta kW_{light\ pjm}$ =((129 – 42)/1000) * 1.0 * 1.18 * 0.084
= 0.0086 kW

ΔkW_{pjm} = 0.0033 + 0.0086
= 0.012 kW

Annual Fossil Fuel Savings Algorithm

Heating penalty from improved lighting:

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

See General Purpose CFL Screw Based, Residential measure (assume ISR = 1.0)

Deemed savings if using defaults provided above:

$$\Delta MMBTUPenalty = - ((((129 – 42) / 1000) * 1.0 * 898 * 0.47 * 0.003412) / 0.84) * 0.625$$

$$= -0.09$$

Annual Water Savings Algorithm

n/a

Incremental Cost

For this time of sale measure, the Incremental cost per unit is assumed to be \$46.[387]

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.

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:

$$\Delta kWH^{388} = ((GPMbase - GPMlow) \times Time_{shower} \times \#\ people \times Showers_{Person} \times days/year\ /\ ShowerHeads/home) \times 8.3 \times (TEMPsh - TEMPin)\ /\ DHW\ Recovery\ Efficiency\ /\ 3{,}412$$

Where:

GPMbase = Gallons Per Minute of baseline showerhead
= 2.5 [389] *or actual flow rate if recorded*
GPMlow = Gallons Per Minute of low flow showerhead

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[388] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all showerhead installations.

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

= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.

 # people = Number of people per household, if unknown, use 2.53 [390]

$Time_{Shower}$ = 7.8 minutes[391]

$Showers_{Person}$ = Average showers per person per day

=0.6[392]

days/year = Days shower used per year

= 365

ShowerHeads/home = Average number of showers in the home

= 1.3 [393]

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 [394]

DHW Recovery Efficiency = Recovery efficiency of electric water heater

= 0.98 [395]

3412 = Constant BTU per kWh

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[390] US Energy Information Administration, Residential Energy Consumption Survey; https://www.eia.gov/consumption/residential/data/2015/hc/php/hc9.7.php

[391] 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

[392] 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

[393] Table 9; Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013

[394] 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.

[395] Electric water heater have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

$$\Delta kWH = ((2.5 – 2.0) \times 7.8 \times 2.53 \times 365 / 1.3) \times 8.3 \times (101 - 60.9) / .98 / 3412$$

$$= 276 \text{ kWh}$$

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

$$\Delta kW = \Delta kWh/hours * CF$$

Where:

Hours = *Average number of hours per year spent using shower head*
=
$=Time_{Shower} \times \# \text{ people} \times Showers_{Person} / 60 \times days /year$
= 7.8 x 2.53 x 0.6 / 60 x 365
= 72 hours

CF = *Summer Peak Coincidence Factor for measure*
= 0.0039 [396]

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

$$\Delta kW = 276 / 72 * 0.0039$$

$$= 0.015 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater:

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[396] 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

ΔMMBTU =

$((GPMbase - GPMlow) \times Time_{shower} \times \# people \times Showers_{Person} \times days/year / ShowerHeads/home) \times 8.3 \times (TEMPsh - TEMPin) / Gas DHW Recovery Efficiency / 10^6$

Where:

Gas DHW Recovery Efficiency = *Recovery efficiency of gas water heater*
= *0.80* [397]

All other variables *As above*

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

ΔMMBTU = ((2.5 – 2.0) x 7.8 x 2.53 x 365 / 1.3) x 8.3 x (101 - 60.9) / .80 / 10^6

= 1.23 MMBTU

Annual Water Savings Algorithm

Water Savings = $((GPMbase - GPMlow) \times Time_{shower} \times \# people \times Showers_{Person} \times days/year / ShowerHeads/home) / 748$

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:

Water Savings = ((2.5 – 2.0) x 7.8 x 2.53 x 365 / 1.3) / 748

= 3.7 CCF

kWh Savings from Water Reduction

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[397] 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%.

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.

$$\Delta kWhwater = 2.07\ kWh/CCF * \Delta Water\ (CCF)$$

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead:

$$\Delta kWh_{water} = 2.07 * 3.7$$
$$= 7.7\ kWh$$

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.[398]

Measure Life

The measure life is assumed to be 10 years.[399]

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.

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[398] Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.

[399] 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.

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:

$$\Delta kWH^{400} = (((GPM_{base} \text{ x } Throttle_{base}) - (GPM_{low} \text{ x } Throttle_{low})) \text{ x } Time_{faucet} \text{ x } \#people \text{ x } days/year \text{ x } DR) \text{ x } 8.3 \text{ x } (Temp_{ft} - Temp_{in}) / \text{DHW Recovery Efficiency} / 3412$$

Where:

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [401] *or actual flow rate if recorded*
GPMlow = Gallons Per Minute of low flow faucet

---

[400] Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.

[401] 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.

= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.

 # people = Average number of people per household

= 2.53 [402]

$Time_{kitchenfaucet}$ = 4.5 minutes[403]

$Time_{bathfaucet}$ = 1.6 minutes

gals/day/person = Average gallons per day used by faucet per person

*= $Time_{faucet}$ * GPM_{base}*

= if unknown, use 6.1

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%[404]

8.3 = Constant to convert gallons to lbs

TEMPft = Assumed temperature of water used by faucet

= 93 kitchen, 86 bathrooms

TEMPin = Assumed temperature of water entering house

= 60.9 [405]

DHW Recovery Efficiency = Recovery efficiency of electric water heater

= 0.98 [406]

0.003412 = Constant to converts MMBTU to kWh

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[402] US Energy Information Administration, Residential Energy Consumption Survey; https://www.eia.gov/consumption/residential/data/2015/hc/php/hc9.7.php

[403] 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

[404] 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.

[405] 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.

[406] See http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator in a kitchen:

$\Delta kWH = (((2.2 \times .83) – (1.5 \times .950)) \times 4.5 \times 2.53 \times 365 \times .5) \times 8.3 \times (93 – 60.9) / 0.98 / 3412$

$= 66.4$ 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:

Hours = *Average number of hours per year spent using faucet*
= *#people x* $Time_{faucet}$ */60 * 365*
= *2.53 x 4.5 / 60 * 365*
= *69 hours*

CF = *Summer Peak Coincidence Factor for measure*
= *0.00262* [407]

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator:

$\Delta kW = 44 / 46 * 0.00262$

$= 0.025$ kW

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater, MMBTU savings provided below:

$\Delta MMBTU = (((GPM_{base} \times Throttle_{base}) – (GPM_{low} \times Throttle_{low})) \times Time_{faucet} \times \#people \times days/year \times DR) \times 8.3 \times (Temp_{ft} - Temp_{in}) / DHW\ Recovery\ Efficiency / 10^6$

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[407] 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

Where:

Gas DHW Recovery Efficiency = *Recovery efficiency of gas water heater*
= *0.80* [408]

All other variables *As above*

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator in a kitchen:

ΔMMBTU = (((2.2 x .83) – (1.5 x .950) x 4.5 x 2.53 x 365 x .5) x 8.3 x (93 – 60.9) / 0.75 / 10^6

= 0.296 MMBTU

Annual Water Savings Algorithm

$$\text{Water Savings} = ((GPM_{base} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Time_{faucet} \times \#people \times days/year \times DR) / 748$$

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:

Water Savings = ((2.2 x .83) – (1.5 x .950)) x 4.6 x 2.53 x 365 x .5 / 748

= 1.114 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.

ΔkWhwater[409] = 2.07 kWh/CCF * ΔWater (CCF)

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[408] 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%.

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator:

$$\Delta kWh_{water} = 2.07\ kWh/CCF * 0.743\ CCF$$
$$= 2.79\ kWh$$

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.[410]

Measure Life

The measure life is assumed to be 10 years.[411]

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.

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[409] 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.

[410] Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.

[411] California DEER Effective Useful Life (EUL) Table – 2014 Update

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

$$\Delta kWh = ((U_{base}A_{base} – U_{insul}A_{base}) * \Delta T * Hours) / (3412 * \eta DHW)$$

Where:

ΔkWh = *Gross customer annual kWh savings for the measure*

U_{base} = *Overall heat transfer coefficient prior to adding tank wrap (BTU/Hr-F-ft^2)*
= *See table below. If unknown assume 1/8* [412]

Uinsul = *Overall heat transfer coefficient after addition of tank wrap (BTU/Hr-F-ft2)*
= *See table below. If unknown assume 1/18* [413]

A_{base} = *Surface area of storage tank prior to adding tank wrap (square feet)*
= *See table below. If unknown assume 23.18* [414]

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[412] Assumptions are from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM) for a poorly insulated 40 gallon tank

[413] Assumes an R-10 tank wrap is added.

[414] 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.

A_{insul} = *Surface area of storage tank after addition of tank wrap (square feet)*
= *See table below. If unknown assume 25.31* [415]
ΔT = *Average temperature difference between tank water and outside air temperature (°F)*
= *60°F* [416]
Hours = *Number of hours in a year (since savings are assumed to be constant over year).*
= *8760*
3412 = *Conversion from BTU to kWh*
ηDHW = *Recovery efficiency of electric hot water heater*
= *0.98* [417]

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

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[415] Ibid.
[416] Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.
[417] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

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
80	12	22	31.84	173	0.020

If tank specifics are unknown assume 40 gallons as an average tank size[418], 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 = kWh savings from tank wrap installation

8760 = 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 size[419], and savings are from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kW = 253 / 8760$$

$$= 0.029 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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[418] 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

[419] 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

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.[420]

Measure Life

The measure life is assumed to be 5 years.[421]

Operation and Maintenance Impacts

n/a

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[420] Based on VEIC online product review.

[421] 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:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 3413$$

Where:

Rexist = Assumed R-value of existing uninsulated piping
= 1.0 [422]
Rnew = R-value of existing pipe plus installed insulation
= Actual

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[422] 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

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°F[423]
8,760 = Hours per year
ηDHW = DHW Recovery efficiency (ηDHW)
= 0.98[424]
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:

$$\Delta kWh = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8{,}760) / 0.98 / 3{,}413$$

$$= 104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / 8{,}760$$

Illustrative example – do not use as default assumption
Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta kW = 104 / 8{,}760$$

$$= 0.012 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

<u>If fossil fuel DHW unit:</u>

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * (L * C) * \Delta T * 8{,}760) / \eta DHW / 1{,}000{,}000$$

Where:

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[423] Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.

[424] Electric water heaters have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

ηDHW = *Recovery efficiency of gas hot water heater*
= *0.75* [425]

Illustrative example – do not use as default assumption
Insulating 4 feet of 0.75” pipe with R-3.5 wrap:

$$\Delta MMBTU = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8{,}760)/ 0.75 / 1{,}000{,}000$$

$$= 0.46 \text{ MMBTU}$$

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 insulation[426].

Measure Life

The measure life is assumed to be 15 years[427].

Operation and Maintenance Impacts

n/a

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[425] 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%

[426] Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

[427] 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.

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 minimum[428].

For 20 - 55 gallons: EF = 0.675 – (0.0015 * rated volume in gallons)
For 55 - 100 gallons: EF = 0.8012 – (0.00078 * rated volume in gallons)

If size is unknown, assume 40 gallons; 0.615 EF.

Definition of Efficient Condition

The efficient condition is a new high efficiency gas water heater meeting or exceeding the minimum efficiency Energy Star qualification criteria provided below[429]:

Water Heater Type	Energy Factor
High Efficiency Gas Storage	0.67
Gas Condensing	0.80
Whole Home Gas Tankless	0.82

Annual Energy Savings Algorithm

n/a

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[428] The Baseline Energy Factor is based on the Federal Minimum Standard for water heaters sold on or after April 16 2015. This ruling can be found here: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

[429] http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (1/ EF_{base} - 1/EF_{efficient}) * (GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{in}) * 1.0)/1,000,000$$

Where:

EF_Baseline = Energy Factor rating for baseline equipment

For <=55 gallons:	0.675 – (0.0015 * tank_size)
For > 55 gallons:	0.8012 – (0.00078 * tank size)

= If tank size unknown assume 40 gallons and EF_Baseline of 0.615

EF_Efficient = Energy Factor Rating for efficient equipment

= Actual. If Tankless whole-house multiply rated efficiency by 0.91[430]. If unknown assume values in look up in table below

Water Heater Type	EF_Efficient
Condensing Gas Storage	0.80
Gas Storage	0.67
Tankless whole-house	0.82 * 0.91 = 0.75

GPD = Gallons Per Day of hot water use per person

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[430] 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.

= 45.5 gallons hot water per day per household/2.53people per household[431]
= 17.6

Household = Average number of people per household

= *2.53* [432]

365.25 = Days per year, on average

γWater = 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* [433]

1.0 = Heat Capacity of water (1 BTU/lb*°F)

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:

ΔMMBTU = (1/0.615 - 1/0.82) * (17.6 * 2.53 * 365.25* 8.33 * (125 – 60.9) * 1) / 1,000,000
= 3.53 MMBTU

Annual Water Savings Algorithm

n/a

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[431] 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

[432] Ibid

[433] 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.

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
Gas Storage	\$159[434]
Condensing gas storage	\$685[435]
Tankless whole-house unit	\$407[436]

Measure Life

The measure life is assumed to be 13 years[437].

Operation and Maintenance Impacts

n/a

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[434] 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.

[435] 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)

[436] 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.

[437] Based on ACEEE Life-Cycle Cost analysis; http://www.aceee.org/node/3068#lcc

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 ≤12kW[438] in place of a standard electric water heater in conditioned space. This is a time of sale measure.

Definition of Baseline Condition

Unless otherwise excepted[439], the baseline condition is assumed to be a new electric water heater meeting federal minimum efficiency standards effective December 29, 2016[440]: Use Efficiency Criteria Table below to calculate EF.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified heat pump water heater[441].

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)

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[438] CFR 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.2

[439] The federal minimum standard for water heaters >55 gallon was increased to EF >= 2.0, compared to an EF >=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.

[440] Docket No. EERE-2015-BT-TP-0007

[441] ENERGY STAR® v3.2 Program Requirements for Residential Water Heaters

	>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 rating[442] 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.[443]

Draw Pattern based on First Hour Rating	
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

ΔkWh = 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)

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[442] CFR part 430 App E 5.4.1

[443] Title 10 → Chapter II → Subchapter D → Part 430 → E → Table 5.4.1

OR, if unknown, by disagregation:

$= GPD * Household * 365.25 * \gamma Water * (TOUT – Tin) * 1.0) / 3412$

GPD = *Gallons Per Day of hot water use per person*

= *45.5 gallons hot water per day per household/2.48*[444] *people per household*

= *18.35*

Household = *Average number of people per household*

= *2.48*

365.25 = *Days per year*

γWater = *Specific weight of water*

= *8.33 pounds per gallon*

T_{OUT} = *Tank temperature*

= *125°F*

T_{IN} = *Incoming water temperature from well or municiple system*

= *60.9* [445]

1.0 = *Heat Capacity of water (1 BTU/lb*°F)*

3412 = *Conversion from BTU to kWh*

kWh_cooling[446] = Cooling savings from conversion of heat in home to water heat

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[444] US Energy Information Administration, Residential Energy Consumption Survey 2015; EIA RECS demographics for South Atlantic regions

[445] 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.

[446] 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

$= (((1/ UEF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412) * LF * 33\% / COP_{COOL})$

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 savings[447]

COP_{COOL} = COP of central air conditioning

= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

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 load[448]

COP_{HEAT} = COP of electric heating system

= actual. If not available, use[449]:

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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.

[447] 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).

[448] 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).

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

Prescriptive savings based on defaults provided above:

ΔkWH electric resistance heat = (((1/0.945 – 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) + kWh_cooling - kWh_heating

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 kWh

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 kWh

ΔkWH electric resistance heat = 1420.7 + 90.7 – 299.1
= 1212.3 kWh

ΔkWH heat pump heat = (((1/0.945 – 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) + kWh_cooling - kWh_heating

kWh_cooling = 90.7 kWh

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 kWh

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[449] 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.

ΔkWH heat pump heat = 1420.7 + 90.7 – 149.5
= 1361.9 kWh

ΔkWH fossil fuel heat = (((1/0.945 – 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) + kWh_cooling - kWh_heating

kWh_cooling = 90.7

kWh_heating = 0

ΔkWH fossil fuel heat = 1420.7 + 90.7 - 0
= 1511.4 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.17 kW[450]

Annual Fossil Fuel Savings Algorithm

ΔMMBTU = - (((1/ UEF_{NEW} * GPD * Household * 365.25 * γWater * ($T_{OUT} – T_{IN}$) * 1.0) / 3412) * LF * 47% * 0.003412) / (ηHeat * % Natural Gas)

Where:

ΔMMBTU = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat.[451]

0.003412 = conversion factor (MMBTU per kWh)

ηHeat = Efficiency of heating system

= Actual.[452] *If not available, use 84%.*[453]

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[450] 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.

[451] 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.

[452] 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

% Natural Gas = Factor dependent on heating fuel:

Heating System	%Natural Gas
Electric resistance or heat pump	*0%*
Natural Gas	*100%*
Unknown heating fuel[454]	*62.5%*

Other factors as defined above

Prescriptive savings based on defaults provided above:

ΔMMBTU for fossil fuel heated homes:

ΔMMBTU = - ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412)) * 0.5 * 0.47 * 0.003412) / (0.72 * 1.0)

= - 1.21MMBTU

Annual Water Savings Algorithm

n/a

Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

[453] 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).

[454] Based on KEMA baseline study for Maryland.

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[455]
60 Gallon Heat Pump Water Heater	2.7	\$460[456]

Measure Life

The expected measure life is assumed to be 13 years.[457]

Operation and Maintenance Impacts

n/a

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[455] 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 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.

[456] NEEP Water Heating, Boiler and Furnace Cost Study September 2018, adjusted to 2019 dollars. Baseline is a unit with UEF of 2.16

[457] 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

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

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * EPG_electric

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	*%ElectricDHW*
Electric	*100%*
Natural Gas	*0%*
Unknown	*24%*[458]

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[458] 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.

GPM_base_S = *Flow rate of the basecase showerhead, or actual if available*

Program	***GPM***
Direct-install, device only	*2.5* [459]
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*

= 0.89 minutes[460]

Household = *Average number of people per household*

= 2.56 [461]

SPCD = *Showers Per Capita Per Day*

= 0.6[462]

365.25 = *Days per year, on average.*

SPH = *Showerheads Per Household so that per-showerhead savings fractions can be determined*

= 1.6 [463]

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

[460] 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.

[461] US Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

[462] Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

[463] 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"

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* [464]

SupplyTemp = *Assumed temperature of water entering house*

= *60.9* [465]

RE_electric = *Recovery efficiency of electric water heater*

= *98%* [466]

3412 = *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:

ΔkWh = 1.0 * (2.5 * 0.89 * 2.56 * 0.6 * 365.25 / 1.6) * 0.11

---

http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/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

[464] 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.

[465] 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.

[466] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

= 86 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/Hours * CF

Where:

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

*= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * 0.746*[467] */ GPH*

GPH = Gallons per hour recovery of electric water heater calculated for 59.1 temp rise (120-60.9), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

= 30.0

*Hours = ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.746 / 30*

= 19.4 hours

CF = Coincidence Factor for electric load reduction

= 0.0015[468]

Illustrative example – do not use as default assumption

For example, a direct installed valve in a home with electric DHW:

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[467] 74.6% is the proportion of hot 120F water mixed with 60.1F supply water to give 105F shower water.

[468] 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

$$\Delta kW = 86 / 19.4 * 0.0015$$

$$= 0.007 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = \%FossilDHW * ((GPM\_base\_S * L\_showerdevice) * Household * SPCD * 365.25 / SPH) * EPG\_gas$$

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	*%Fossil_DHW*
Electric	*0%*
Natural Gas	*100%*
Unknown	*76%*[469]

EPG_gas = Energy per gallon of Hot water supplied by gas

$$= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE\_gas * 1{,}000{,}000)$$

$$= 0.00065 \text{ MMBTU/gal}$$

RE_gas= Recovery efficiency of gas water heater

= 75% For SF homes[470]

1,000,000 = Converts BTUs to MMBTU

---

[469] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Attlantic 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.

[470] 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%.

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:

ΔMMBTU = 1.0 * ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.00065
= 0.51 MMBTU

Water impact Descriptions and calculations

ΔCCF = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / 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:

ΔCCF = ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) / 748
= 1.0 CCF

Measure Life

The expected measure life is assumed to be 10 years.[471]

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is the actual measure cost or $30[472] if not available.

Operation and Maintenance Impacts

N/A

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[471] Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead

[472] Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

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:

$$\Delta kWh^{473} = (UA * (Tpre - Tpost) * Hours) / (3412 * RE\_electric)$$

Where:

U = Overall heat transfer coefficient of tank (BTU/Hr-°F-ft^2).

= Actual if known. If unknown assume R-12, U = 0.083

A = Surface area of storage tank (square feet)

---

[473] 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.

= 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)*[474]
30	*19.16*
40	*23.18*
50	*24.99*
80	*31.84*

Tpre = Actual hot water setpoint prior to adjustment.

= 135 degrees default

Tpost = 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

= 0.98 [475]

The deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔkWh = (UA * (Tpre – Tpost) * Hours) / (3412 * RE_electric)

---

[474] 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.

[475] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

= (((0.083 * 24.99) * (135 – 120) * 8760) / (3412 * 0.98)

= 81.5 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh / Hours

Where:

Hours = 8760

The deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔkW = (81.5/ 8760)

= 0.0093 kW

Annual Fossil Fuel Savings Algorithm

For homes with gas water heaters:

ΔMMBTU = (U * A * (Tpre – Tpost) * Hours) / (1,000,000 * RE_gas)

Where

1,000,000 = Converts BTUs to MMBTU (BTU/MMBTU)

RE_gas = Recovery efficiency of gas water heater

= 0.75 [476]

The deemed savings assumption, where site specific assumptions are not available would be as follows:

ΔMMBTU = (U * A * (Tpre – Tpost) * Hours) / (1,000,000 * RE_gas)

= (0.083 * 24.99 * (135 – 120) * 8760) / (1,000,000 * 0.75)

= 0.36 MMBTU

---

[476] 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%.

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

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, ENERGY STAR Most Efficient/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	>= 2.38	>= 2.06[477]	<= 3.7	<= 4.3[478]
ENERGY STAR Most Efficient, CEE TIER 2	>= 2.74	>= 2.74	<= 3.2	<= 3.2
CEE TIER 3	>= 2.92	>= 2.92	<= 3.2	<= 3.2

ENERGY STAR has a new draft specification version 8.0 expected to go into effect as of January 1, 2018[479]. Once this specification is in place, front loading clothes washers will need a minimum IMEF of 2.76 and a maximum IWF of 3.2. Top loading washers are unaffected.

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 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.

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[477] CEE does not distinguish between front loading and top loading, and requires a minimum IMEF of 2.38 in both cases

[478] CEE does not distinguish between front loading and top loading, and requires a maximum IWF of 3.7 in both cases

[479] https://www.energystar.gov/sites/default/files/asset/document/Final%20Draft%20ENERGY%20STAR%20Version%208.0%20Clothes%20Washer%20Cover%20Memo.pdf

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 changes as of January 1, 2018. The baseline for before and after January 1, 2018 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
Before Jan 1, 2018	1.84	1.29	4.7	8.4
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, ENERGY STAR Most Efficient/CEE Tier 2 or CEE TIER 3 efficiency criteria presented above.

Annual Energy Savings Algorithm

ΔkWh = [(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 feet*[480]

IMEFbase = *Integrated Modified Energy Factor of baseline unit*

---

[480] 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.

= *Values provided in table below*

IMEFeff = *Integrated Modified Energy Factor of efficient unit*
= *Actual. If unknown assume average values provided below.*

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages[481]	
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading
Federal Standard	>= 1.84	>= 1.29	>= 1.66	67%	33%
ENERGY STAR, CEE Tier 1	>= 2.38	>= 2.06	>= 2.26	62%	38%
ENERGY STAR Most Efficient, CEE TIER 2	>= 2.74	>= 2.74	>= 2.74	98%	2%
CEE TIER 3	>= 2.92	n/a	>= 2.92	100%	0%

Ncycles = *Number of Cycles per year*
= *254*[482]

%CW = *Percentage of total energy consumption for Clothes Washer operation*

%DHW = *Percentage of total energy consumption used for water heating*

%Dryer = *Percentage of total energy consumption for dryer operation*
(dependent on efficiency level – see table below)

	Percentage of Total Energy Consumption[483]		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%

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[481] Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

[482] 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.

[483] 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. See "2015 Clothes Washer Analysis.xls" for the calculation.

ENERGY STAR, CEE Tier 1	8%	.23%	69%
ENERGY STAR Most Efficient, CEE TIER 2	14%	10%	76%
CEE TIER 3	14%	10%	76%

%Electric_DHW = *Percentage of DHW savings assumed to be electric*

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	65%[484]

%Electric_Dryer = *Percentage of dryer savings assumed to be electric*

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%
Unknown	79%[485]

The prescriptive kWH savings based on values provided above where DHW and Dryer fuels are unknown is provided below[486]:

Efficiency Level	ΔkWH		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	112.7	84.2	102.2
ENERGY STAR Most Efficient, CEE TIER 2	145.0	145.0	145.0
CEE TIER 3	160.9	n/a	160.9

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[484] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

[485] 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.

[486] 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.

The unit specific kWh savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Dryer/DHW Gas Combo	ΔkWH		
		Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	160.0	104.9	140.1
	Electric Dryer/Gas DHW	59.8	79.7	66.3
	Gas Dryer/Electric DHW	101.7	47.8	82.6
	Gas Dryer/Gas DHW	1.5	22.5	8.8
ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	208.4	210.7	208.5
	Electric Dryer/Gas DHW	74.5	138.3	76.0
	Gas Dryer/Electric DHW	129.7	99.1	129.1
	Gas Dryer/Gas DHW	-4.1	26.7	-3.5
CEE TIER 3	Electric Dryer/Electric DHW	228.1	n/a	228.1
	Electric Dryer/Gas DHW	92.4	n/a	92.4
	Gas Dryer/Electric DHW	134.4	n/a	134.4
	Gas Dryer/Gas DHW	-1.4	n/a	-1.4

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:

Hours = *Assumed Run hours of Clothes Washer*
= *265* [487]
CF = *Summer Peak Coincidence Factor for measure*
= *0.029* [488]

The prescriptive kW savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

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[487] 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.

[488] Ibid.

Efficiency Level	ΔkW		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	0.012	0.009	0.011
ENERGY STAR Most Efficient, CEE TIER 2	0.016	0.018	0.016
CEE TIER 3	0.018	n/a	0.018

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	0.018	0.011	0.015
	Electric Dryer/Fuel DHW	0.007	0.009	0.007
	Fuel Dryer/Electric DHW	0.011	0.005	0.009
	Fuel Dryer/Fuel DHW	0.000	0.002	0.001
ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	0.023	0.023	0.023
	Electric Dryer/Fuel DHW	0.008	0.015	0.008
	Fuel Dryer/Electric DHW	0.014	0.011	0.014
	Fuel Dryer/Fuel DHW	0.000	0.003	0.000
CEE TIER 3	Electric Dryer/Electric DHW	0.025	n/a	0.025
	Electric Dryer/Fuel DHW	0.010	n/a	0.010
	Fuel Dryer/Electric DHW	0.015	n/a	0.015
	Fuel Dryer/Fuel DHW	0.000	n/a	0.000

Annual Fossil Fuel Savings Algorithm

ΔMMBTU = [(Capacity * 1/IMEFbase * Ncycles) * ((%DHWbase * %Natural Gas_DHW * R_eff) + (%Dryerbase * %Gas _Dryer)] - [(Capacity * 1/IMEFeff * Ncycles) * ((%DHWeff * %Natural Gas_DHW * R_eff) + (%Dryereff * %Gas_Dryer)] * MMBTU_convert

Where:

R_eff = *Recovery efficiency factor*
= *1.31*[489]

---

[489] To account for the different efficiency of electric and Natural Gas water heaters (gas water

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	35%[490]

%Gas_Dryer = *Percentage of dryer savings assumed to be Natural Gas*

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	6%[491]

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	0.16	0.05	0.12
ENERGY STAR Most Efficient, CEE TIER 2	0.22	0.13	0.22
CEE TIER 3	0.22	n/a	0.22

The unit specific MMBTU savings when DHW and Dryer fuels are known is provided below:

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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.

[490] Default assumption for unknown fuel is based on percentage of homes with gas DHW from EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

[491] Default assumption for unknown is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

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	0.43	0.11	0.32
	Gas Dryer/Electric DHW	0.20	0.19	0.20
	Gas Dryer/Gas DHW	0.63	0.30	0.51
ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	0.00	0.00	0.00
	Electric Dryer/Gas DHW	0.58	0.31	0.57
	Gas Dryer/Electric DHW	0.27	0.38	0.27
	Gas Dryer/Gas DHW	0.84	0.69	0.84
CEE TIER 3	Electric Dryer/Electric DHW	0.00	n/a	0.00
	Electric Dryer/Gas DHW	0.58	n/a	0.58
	Gas Dryer/Electric DHW	0.32	n/a	0.32
	Gas Dryer/Gas DHW	0.90	n/a	0.90

Annual Water Savings Algorithm

ΔWater (CCF) = (Capacity * (IWFbase - IWFeff)) * 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[492]		
	Front Loading	Top Loading	Weighted Average
Federal Standard	4.7	8.4	5.92
ENERGY STAR, CEE Tier 1	3.7	4.3	3.93
ENERGY STAR Most Efficient, CEE TIER 2	3.2	3.5	3.21
CEE TIER 3	3.2	3.2	3.2

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[492] 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	2.6	1.9	2.3
ENERGY STAR Most Efficient, CEE TIER 2	3.2	2.8	3.2
CEE TIER 3	3.2	6.9	3.2

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.

ΔkWh_{water}[493] = 2.07 kWh * ΔWater (CCF)

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	ΔkWhwater		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	5.4	3.9	4.8
ENERGY STAR Most Efficient, CEE TIER 2	6.6	5.9	6.6
CEE TIER 3	6.6	14.4	6.6

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided in the table below:[494]

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[493] 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.

[494] 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

Purchase Date	Efficiency Level	Front Loading	Top Loading
Before Jan 1, 2018	ENERGY STAR, CEE Tier 1	$17	$17
	ENERGY STAR Most Efficient, CEE TIER 2	$28	$28
	CEE TIER 3	$34	$34
After Jan 1, 2018	ENERGY STAR, CEE Tier 1	$17	$21
	ENERGY STAR Most Efficient, CEE TIER 2	$28	$50
	CEE TIER 3	$34	NA

Measure Life

The measure life is assumed to be 14 years [495].

Operation and Maintenance Impacts

n/a

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labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

[495] 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

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, ENERGY STAR Most Efficient / 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	>= 2.38	>= 2.06[496]	<= 3.7	<= 4.3[497]
ENERGY STAR Most Efficient, CEE TIER 2	>= 2.74	>= 2.74	<= 3.2	<= 3.2
CEE TIER 3	>= 2.92	>= 2.92	<= 3.2	<= 3.2

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 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.

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[496] CEE does not distinguish between front loading and top loading, and requires a minimum IMEF of 2.38 in both cases

[497] CEE does not distinguish between front loading and top loading, and requires a maximum IWF of 3.7 in both cases

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 years[498], 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 7.93WF.

The new baseline unit is consistent with the Time of Sale measure.

The baseline assumptions are provided below:

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 before Jan 1, 2018	1.84	1.29	4.7	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 exceeding ENERGY STAR/ CEE Tier 1, ENERGY STAR Most Efficient / CEE Tier 2 or CEE Tier 3 standards as of 1/1/2015 as presented in the measure description.

Annual Energy Savings Algorithm

(see ‘2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls’ for detailed calculation)

$$\Delta kWh = [(Capacity * 1/IMEFbase * Ncycles) * (\%CWbase + (\%DHWbase * \%Electric\_DHW) + (\%Dryerbase * \%Electric\_Dryer)] - [(Capacity *$$

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[498] Based on 1/3 of the measure life.

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 feet*[499]
IMEFbase = *Integrated Modified Energy Factor of baseline unit*
= *Values provided in table below*
IMEFeff = *Integrated Modified Energy Factor of efficient unit*
= *Actual. If unknown assume average values provided below.*

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages[500]	
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading
Existing Unit[501]	1.0	0.84	n/a[502]	n/a	n/a
Federal Standard	>= 1.84	>= 1.29	>= 1.66	67%	33%
ENERGY STAR, CEE Tier 1	>= 2.38	>= 2.06	>= 2.26	62%	38%
ENERGY STAR Most Efficient, CEE TIER 2	>= 2.74	>= 2.74	>= 2.74	98%	2%
CEE TIER 3	>= 2.92	n/a	>= 2.92	100%	0%

Ncycles = *Number of Cycles per year*
= *254*[503]
%CW = *Percentage of total energy consumption for Clothes Washer operation*
%DHW = *Percentage of total energy consumption used for water heating*

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[499] 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.

[500] Weighting percentages are based on available product from the CEC database.

[501] Existing units efficiencies are based upon an MEF of 1.26 , the 2004 Federal Standard, converted to IMEF using an ENERGY STAR conversion tool.

[502] For early replacement measures we will always know the configuration of the replaced machine.

[503] 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.

%Dryer *= Percentage of total energy consumption for dryer operation*
(dependent on efficiency level – see table below)

	Percentage of Total Energy Consumption[504]		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%
ENERGY STAR, CEE Tier 1	8%	23%	69%
ENERGY STAR Most Efficient, 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%
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	Front	Top	Front	Top

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[504] 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.

				Average				
ENERGY STAR, CEE TIER 1	Electric Dryer/Electric DHW	488.7	655.6	140.1	29%	21%	292.6	365.6
	Electric Dryer/Gas DHW	316.3	397.0	66.3	21%	17%	175.6	210.9
	Gas Dryer/Electric DHW	208.4	305.1	82.6	40%	27%	137.6	180.0
	Gas Dryer/Gas DHW	36.0	46.5	8.8	25%	19%	20.7	25.3
ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	556.5	723.4	208.5	37%	29%	360.7	433.7
	Electric Dryer/Gas DHW	325.5	406.2	76.0	23%	19%	185.1	220.4
	Gas Dryer/Electric DHW	254.6	351.4	129.1	51%	37%	184.0	226.3
	Gas Dryer/Gas DHW	23.6	34.2	-3.5	-15%	-10%	8.4	13.0
CEE TIER 3	Electric Dryer/Electric DHW	576.1	743.0	228.1	40%	31%	380.3	453.3
	Electric Dryer/Gas DHW	341.9	422.6	92.4	27%	22%	201.5	236.8
	Gas Dryer/Electric DHW	259.9	356.7	134.4	52%	38%	189.3	231.6
	Gas Dryer/Gas DHW	25.7	36.3	-1.4	-5%	-4%	10.4	15.1

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

Hours = *Assumed Run hours of Clothes Washer*
= *265*[505]

CF = *Summer Peak Coincidence Factor for measure*
= *0.029*[506]

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	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top	Weighted Average	Front	Top	Front	Top
ENERGY STAR,	Electric Dryer/Electric DHW	0.053	0.072	0.015	29%	21%	0.033	0.042

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[505] 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.

[506] Ibid.

CEE Tier 1	Electric Dryer/Fuel DHW	0.035	0.043	0.007	21%	17%	0.020	0.024
	Fuel Dryer/Electric DHW	0.023	0.033	0.009	40%	27%	0.016	0.021
	Fuel Dryer/Fuel DHW	0.004	0.005	0.001	25%	19%	0.002	0.003
ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	0.061	0.079	0.023	37%	29%	0.041	0.050
	Electric Dryer/Fuel DHW	0.036	0.044	0.008	23%	19%	0.021	0.025
	Fuel Dryer/Electric DHW	0.028	0.038	0.014	51%	37%	0.021	0.026
	Fuel Dryer/Fuel DHW	0.003	0.004	0.000	-15%	-10%	0.001	0.001
CEE TIER 3	Electric Dryer/Electric DHW	0.063	0.081	0.025	40%	31%	0.043	0.052
	Electric Dryer/Fuel DHW	0.037	0.046	0.010	27%	22%	0.023	0.027
	Fuel Dryer/Electric DHW	0.028	0.039	0.015	52%	38%	0.022	0.026
	Fuel Dryer/Fuel DHW	0.003	0.004	0.000	-5%	-4%	0.001	0.002

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:

$$\Delta\text{MMBTU} = [(\text{Capacity} * 1/\text{IMEFbase} * \text{Ncycles}) * ((\%\text{DHWbase} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryerbase} * \%\text{Gas \_Dryer})] - [(\text{Capacity} * 1/\text{IMEFeff} * \text{Ncycles}) * ((\%\text{DHWeff} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryereff} * \%\text{Gas\_Dryer})] * \text{MMBTU\_convert}$$

Where:

R_eff = Recovery efficiency factor
= 1.26[507]
MMBTU _convert = Convertion 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%

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[507] 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.

%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	0.74	1.11	0.32	43%	29%	0.50	0.66
	Gas Dryer/Electric DHW	0.96	1.20	0.20	20%	16%	0.53	0.63
	Gas Dryer/Gas DHW	1.70	2.31	0.51	30%	22%	1.03	1.30
ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	0.00	0.00	0.00	n/a	n/a	0.00	0.00
	Electric Dryer/Gas DHW	0.99	1.36	0.57	57%	42%	0.76	0.92
	Gas Dryer/Electric DHW	1.03	1.27	0.27	26%	21%	0.60	0.71
	Gas Dryer/Gas DHW	2.02	2.63	0.84	42%	32%	1.36	1.62
CEE TIER 3	Electric Dryer/Electric DHW	0.00	n/a	0.00	n/a	n/a	0.00	0.00
	Electric Dryer/Gas DHW	1.01	1.38	0.58	58%	42%	0.77	0.93
	Gas Dryer/Electric DHW	1.08	1.32	0.32	30%	24%	0.65	0.76
	Gas Dryer/Gas DHW	2.09	2.70	0.90	43%	34%	1.42	1.69

Annual Water Savings Algorithm

ΔWater (CCF) = (Capacity * (IWFbase - IWFeff)) * 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**[508]		
	Front Loading	**Top Loading**	**Weighted Average**
Existing[509]	8.2	8.4	n/a[510]
Federal Standard	4.7	8.4	5.92
ENERGY STAR, CEE Tier 1	3.7	4.3	3.9
ENERGY STAR Most Efficient, CEE TIER 2	3.2	3.5	3.21
CEE TIER 3	3.2	3.3	3.2

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below[511]:

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	0.00	0.00
Federal Standard	n/a	n/a	n/a	n/a	n/a	0.00	0.00
ENERGY STAR, CEE Tier 1	5.3	5.2	2.3	47%	44%	3.5	3.6

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[508] Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database.

[509] 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.

[510] For early replacement measures we will always know the configuration of the replaced machine.

[511] 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/)

ENERGY STAR Most Efficient, CEE TIER 2	5.8	6.1	3.2	54%	52%	4.3	4.4
CEE TIER 3	5.9	6.1	3.2	54%	52%	4.4	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.

ΔkWh_{water}[512] $= 2.07\ kWh * \Delta Water\ (CCF)$

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	
	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	11	10.8	4.8	47%	44%	7.2	7.5
ENERGY STAR Most Efficient, CEE TIER 2	12.1	12.6	6.6	54%	52%	9.0	9.2
CEE TIER 3	12.1	12.6	6.6	54%	52%	9.0	9.2

Incremental Cost

The lifecycle NPV incremental cost for this early replacement measure is provided in the table below:[513]

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[512] 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.

[513] 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

Purchase Date	Efficiency Level	Front Loading	Top Loading
Before Jan 1, 2018	ENERGY STAR, CEE Tier 1	$444	$348
	ENERGY STAR Most Efficient, CEE TIER 2	$455	$378
	CEE TIER 3	$461	NA
After Jan 1, 2018	ENERGY STAR, CEE Tier 1	$444	$354
	ENERGY STAR Most Efficient, CEE TIER 2	$455	$455
	CEE TIER 3	$427	NA

Measure Life

The measure life is assumed to be 14 years [514] and the existing unit is assumed to have a remaining life of 5 years[515].

Operation and Maintenance Impacts

n/a

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labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

[514] 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

[515] Based on 1/3 of the measure life.

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 4.0)[516] 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)[517]
Up to 35	≥1.35
> 35 to ≤45	≥1.50
> 45 to ≤ 54	≥1.60
> 54 to ≤ 75	≥1.70
> 75 to ≤ 185	≥2.50

Capacity (pints/day)	Federal Standard Criteria after 6/13/2019 (L/kWh)[518]
Up to 25	≥1.30
> 25 to ≤50	≥1.60
> 50.01	≥2.80

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[516] Energy Star Version 4.0 became effective 10/25/16

[517] 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

[518] 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

Definition of Efficient Condition

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards version 4.0 effective 10/25/2016[519] 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
(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

$\Delta kWh = Capacity * 0.473 / 24 * Hours * (1 / (L/kWh\_Base) – 1 / (L/kWh\_Eff))$

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
= 1632 [520]
L/kWh = Liters of water per kWh consumed, as provided in tables above

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[519] https://www.energystar.gov/products/spec/dehumidifiers_specification_version_4_0_pd

[520] 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

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		
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

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

Hours = *Annual operating hours*
= *1632 hours*[521]
CF = *Summer Peak Coincidence Factor for measure*
= *0.37* [522]

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

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[521] 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

[522] 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%

Average	0.044

After 10/31/19:

Capacity	ΔkW
(pints/day) Range	
≤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 $5[523].

Measure Life

The measure life is assumed to be 12 years.[524]

Operation and Maintenance Impacts

n/a

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[523] 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

[524] ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

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 =

$$Capacity\ x\frac{.473}{24}\ x\ hours\ x\frac{1}{L\ per\ kWh}\ x\ (Service\ Life - Existing\ Age)$$

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*
= *1632* [525]
L/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.*
Service Life = *12*
Existing Age = *age of existing unit*

---

[525] 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

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)[526]**	**2012 Federal Standard (≥ L/kWh)[527]**	**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
> 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

$$\Delta \mathrm{kW} = \frac{\Delta \mathrm{kWh}}{Hours} \mathrm{x\ CF}$$

Where:

kWh = annual kWh savings

Hours = Annual operating hours

= 1632 hours[528]

CF = Summer Peak Coincidence Factor for measure

= 0.37 [529]

---

[528] Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

[529] 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

Capacity (pints/day) Range	ΔkW before 2012	ΔkW 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

STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

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, 2011[530].

Definition of Efficient Condition

The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below.

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[531] to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
- 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

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[530] ENERGY STAR Appliance Savings Calculator; http://www.energystar.gov/buildings/sites/default/uploads/files/appliance_calculator.xlsx?7224-046c=&7224-__046ceiling_fan_calculator_xlsx=&a0f2-2e6f&a0f2-2e6f

[531] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard

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

Where:

kWh_{BASE} = Baseline kWh consumption per year[532]

= see table below

kWh_{ESTAR} = ENERGY STAR kWh consumption per year[533]

= 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

$$\Delta kW = \Delta kWh/Hours * CF$$

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5840 hours[534]

CF = Summer Peak Coincidence Factor for measure

---

[532] 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.

[533] Ibid.
Efficiency 3.0 CADR/Watt, 16 hours a day, 365 days a year and 0.6W standby power.

[534] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

= 0.67[535]

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.[536]

Measure Life

The measure life is assumed to be 9 years[537].

Operation and Maintenance Impacts

There are no operation and maintenance cost adjustments for this measure.[538]

---

[535] Assumes appliance use is equally likely at any hour of the day or night.

[536] ENERGY STAR Appliance Savings Calculator, which cites “EPA research on available models, 2012”

[537] ENERGY STAR Appliance Savings Calculator; Based on Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

[538] 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.

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 dryers[539]. 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

Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

Annual Energy Savings Algorithm

$$\Delta kWh = (Load/CEFbase - Load/CEFeff) * Ncycles * \%Electric$$

Where:

Load = *The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.*

---

[539] 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

Dryer Size	*Load (lbs.)*[540]
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 analysis*[541]*. 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*
Vented Gas	*2.84*[542]

CEFeff = *CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.*[543] *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*[544]

Ncycles = *Number of dryer cycles per year*

= *311 cycles per year.*[545]

---

[540] Based on ENERGY STAR test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[541] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

[542] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

[543] ENERGY STAR Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[544] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

[545] Ecova, ‘Dryer Field Study’, Northwest Energy Efficiency Alliance (NEEA) 2014.

%Electric = The percent of overall savings coming from electricity

Clothes Dryer Fuel Type	*%Electric* [546]
Electric	*100%*
Gas	*16%*

Product Class	Algorithm	ΔkWh
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	= ((8.45/3.11 – 8.45/3.93) * 311 * 100%)	176.3
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	= ((3/3.01 – 3/3.80) * 311 * 100%)	64.4
Vented Electric, Compact (240V) (< 4.4 ft^3)	= ((3/2.73 – 3/3.45) * 311 * 100%)	71.3
Ventless Electric, Compact (240V) (< 4.4 ft^3)	= ((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

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer.

=290 hours per year.[547]

CF = Summer Peak Coincidence Factor for measure

= 2.9%[548]

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

---

[546] %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.

[547] Assumes average of 56 minutes per cycle based on Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014

[548] 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.

Annual Fossil Fuel Savings Algorithm

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

ΔMMBTU = (Load/CEFbase – Load/CEFeff) * Ncycles * MMBTU_convert * %Gas

Where:

MMBTU_convert = Conversion factor from kWh to MMBTU

= 0.003413

%Gas = Percent of overall savings coming from gas

Clothes Dryer Fuel Type	*%Gas* [549]
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.[550]

---

[549] %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.

[550] Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”

Measure Life

The expected measure life is assumed to be 14 years[551].

Operation and Maintenance Impacts

n/a

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[551] 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

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 below[552]:

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
Standard	270	3.50

Annual Energy Savings Algorithm

$$\Delta kWh^{553} = ((kWh_{Base} - kWh_{ESTAR}) * (\%kWh\_op + (\%kWh\_heat * \%Electric\_DHW)))$$

Where:

kWh_{BASE} = Baseline kWh consumption per year

---

[552] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

[553] 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.

= 307 kWh

kWh_{ESTAR} *= ENERGY STAR kWh annual consumption = 270*

%kWh_op = Percentage of dishwasher energy consumption used for unit operation

= 1 - 56%[554]

= 44%

%kWh_heat = Percentage of dishwasher energy consumption used for water heating

= 56%[555]

%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	*%Electric_DHW*
Electric	*100%*
Natural Gas	*0%*
Unknown	*65%*[556]

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

ΔkW = ΔkWh/Hours * CF

Where:

Hours = Annual operating hours[557]

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[554] ENERGY STAR Dishwasher Calculator, see 'EnergyStarCalculatorConsumerDishwasher.xls'.

[555] Ibid.

[556] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the Mid-Atlantic region.

[557] 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/

= 210 hours

CF *= Summer Peak Coincidence Factor*

= 2.6%[558]

DHW Fuel	Algorithm	ΔkW
Electric	= 37/210 * 0.026	0.0046
Unknown	= 29.75/210 * 0.02	0.0037

Annual Fossil Fuel Savings Algorithm

ΔMMBTU = $(kWh_{Base} - kWh_{ESTAR})$ * %kWh_heat * %Natural Gas_DHW * R_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*

DHW fuel	*%Natural Gas_DHW*
Electric	*0%*
Natural Gas	*100%*
Unknown	*35%*[559]

R_eff *= Recovery efficiency factor*

---

[558] 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.

[559] 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.

= 1.31[560]

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

Annual Water Savings Algorithm

ΔCCF = $(Water_{Base} - Water_{EFF})$ * GalToCCF

Where

$Water_{Base}$ = *annual water consumption of conventional unit*

= 700 gallons[561]

$Water_{EFF}$ = *annual water consumption of efficient unit:*

ENERGY STAR Specification	WaterEFF (gallons)
6.0	490[562]

GalToCCF = factor to convert from gallons to CCF

= 0.001336

---

[560] 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.

[561] 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/

[562] 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/

ENERGY STAR Specification	Algorithm	ΔCCF
6.0	= (700 – 490) * 0.001336	0.28

Incremental Cost

The lifecycle NPV incremental capital cost for this time of sale measure is $0[563].

Measure Life

The measure life is assumed to be 10 years[564].

Operation and Maintenance Impacts

n/a

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[563] Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”

[564] ENERGY STAR Dishwasher Calculator, see ‘EnergyStarCalculatorConsumerDishwasher.xls’.

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 practices[565]. 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

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

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

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[565] See BPI Building Analyst and Envelope Professional standards, http://www.bpi.org/standards_approved.aspx

Cooling savings from reduction in Air Conditioning Load:

$$\Delta kWh_{cool} = [(((CFM50Exist - CFM50New) / N\text{-}cool) * 60 * CDH * DUA * 0.018) / 1{,}000 / \eta Cool] * LM$$

Where:

CFM50exist = *Blower Door result (CFM_{50}) prior to air sealing*
= *actual*

CFMnew = *Blower Door result (CFM_{50}) after air sealing*
= *actual*

N-cool = *conversion from CFM_{50} to $CFM_{Natural}$*[566]
= *dependent on* location and number of stories:[567]

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 Hours*[568]
= *dependent on location:*

Location	***Cooling Degree Hours (75°F set point)***
Wilmington, DE	*7,514*

---

[566] 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

[567] 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".

[568] 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)

Baltimore, MD	*9,616*
Washington, DC	*13,178*

DUA = *Discretionary Use Adjustment*[569]
= *0.75*

0.018 = *The volumetric heat capacity of air (BTU/ft3°F)*

ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available, use*[570]*:*

Age of Equipment	***SEER Estimate***
Before 2006	*10*
After 2006	*13*

LM = *Latent Multiplier to account for latent cooling demand*[571]

Location	**LM**
Wilmington, DE	4.09
Baltimore, MD	3.63
Washington, DC	3.63

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.

ΔkWh_{cool} = [(((3,400 – 2,250) / 38.4) *60 * 7,514 * 0.75 * 0.018) / 1,000 / 12] * 4.09

= 62.1 kWh

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[569] 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.

[570] 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.

[571] Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

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

$$\Delta kWh_{heat} = ((((CFM50Exist – CFM50New) / N\text{-}heat) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat) * 293.1$$

Where:

N-heat = *conversion from* CFM_{50} *to* $CFM_{Natural}$
= *Based on location and* number of stories[572]*:*

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*
= *dependent on location*[573]

Location	*Heating Degree Days (60°F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available, use*[574]*:*

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[572] 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”.

[573] 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.

[574] 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

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*[575]
Heat Pump	*Before 2006*	*6.8*	*2.00*
	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.

$$\Delta kWh_{heat} = [(((3{,}400 - 2{,}250) / 24.5) * 60 * 24 * 3{,}275 * 0.018) / 1{,}000{,}000 / 2.5] * 293.1$$

$$= 467.1 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW_{cool} = \Delta kWh / FLHcool * CF$$

Where:

FLHcool = Full Load Cooling Hours
= Dependent on location as below:

Location	**FLHcool**
Wilmington, DE	*524* [576]
Baltimore, MD	*542* [577]
Washington, DC	*681*

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average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate.

[575] To convert HSPF to COP, divide the HSPF rating by 3.413.

[576] 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)

[577] 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.

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= 0.69[578]

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*
= 0.66[579]

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.

ΔkW = 62.1 / 524 * 0.69

= 0.08 kW

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

ΔMMBTU = (((CFM50Exist – CFM50New) / N-heat) *60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat

Where:

N-heat = *conversion from* CFM_{50} *to* $CFM_{Natural}$
= Based on location and number of stories[580]*:*

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[578] 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.

[579] 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.

[580] 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".

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*
= *dependent on location*[581]

Location	*Heating Degree Days (60°F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

ηHeat = *Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*
= *actual*[582]*. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[583]*.*

Illustrative example – do not use as default assumption

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[581] 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.

[582] 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.

[583] 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.

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.

$$\Delta MMBTU = (((3{,}400 – 2{,}250) / 24.5) * 60 * 24 * 3{,}275 * 0.018) / 1{,}000{,}000 / 0.7$$

$$= 5.7 \text{ MMBTU}$$

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 yrs[584].

Operation and Maintenance Impacts

n/a

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[584] 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 insulation[585]. 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 floor /roof assembly and include the effective R-value of any existing insulation that is left in situ.

Annual Energy Savings Algorithm

<u>Savings from reduction in Air Conditioning Load:</u>

$$\Delta kWh = ((1/Rexist - 1/Rnew) * CDH * DUA * Area) / 1{,}000 / \eta Cool * Adjcool$$

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[585] 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.

Where:

Rexist = R-value of roof assembly plus any existing insulation
= actual (minimum of R-5)
Rnew = R-value of roof assembly plus new insulation
= actual
CDH = Cooling Degree Hours[586]
= dependent on location:

Location	*Cooling Degree Hours (75°F set point)*
Wilmington, DE	*7,514*
Baltimore, MD	*9,616*
Washington, DC	*13,178*

DUA = Discretionary Use Adjustment[587]
= 0.75
Area = square footage of area covered by new insulation
= actual
ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available, use[588]*:*

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

Adj_{cool} = 0.8[589]

Illustrative example – do not use as default assumption

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[586] 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/)

[587] 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.

[588] 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.

[589] 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.

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.

$$\Delta kWh = ((1/5 – 1/30) * 9{,}616 * 0.75 * 1{,}200) / 1{,}000 / 12 * 0.8$$

$$= 96 \text{ kWh}$$

<u>Savings for homes with electric heat (Heat Pump or resistance):</u>

$\Delta kWh = (((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat) * 293.1 * Adjheat$

HDD = *Heating Degree Days*
= *dependent on location*[590]

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

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available, use*[591]*:*

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*

293.1 = Converts MMBTU to kWh

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[590] 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.

[591] 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.

Adjheat = 0.6[592]

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

$$\Delta kW = \Delta kWh / FLHcool * CF$$

Where:

FLHcool = *Full Load Cooling Hours*
= *Dependent on location as below:*

Location	FLHcool
Wilmington, DE	*524* [593]
Baltimore, MD	*542* [594]
Washington, DC	*681*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [595]

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*
= *0.66* [596]

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[592] From Illinois TRM, 9 as demonstrated in two years of metering evaluation by Opinion Dynamics

[593] 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)

[594] 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.

[595] 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.

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.

$$\Delta kW = 96 / 542 * 0.69$$

$$= 0.12 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat * Adjheat$$

Where:

HDD = Heating Degree Days
= dependent on location[597]

Location	*Heating Degree Days (60°F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

*ηHeat = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*
= actual[598]*. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[599]*.*

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[596] 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.

[597] 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.

[598] 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.

[599] 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

Adjheat = 0.60[600]

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.

$$\Delta MMBTU = ((1/5 – 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 0.75 * .60$$

$$= 13\ MMBTU$$

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 insulation work.

Measure Life

The measure life is assumed to be 25 years[601].

Operation and Maintenance Impacts

n/a

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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.

[600] 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.

[601] 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.

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 [602]

Heating kWh Savings (Electric Resistance) = 356 kWh per 100 square feet window area

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

$$\Delta kWcooling = \Delta kWREM * CF$$

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[602] 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.

Where:

$\Delta kWREM$ = 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)
= 0.69 [603]

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
= 0.66 [604]

ΔkW_{SSP} cooling = 0.12 * 0.69

= 0.083 kW per 100 square feet of windows

ΔkW_{PJM} 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.[605]

Measure Life

The measure life is assumed to be 25 years.[606]

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[603] 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.

[604] 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.

[605] $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.

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

Operation and Maintenance Impacts

n/a

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

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 Algorithm[607]

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

Where:

$kWh_{cooling}$ = *reduction in cooling requirement. Only applicable to homes with central cooling*
$= ((1 / R\_Old\_AG - 1/(R\_Old\_AG + R\_Added\_AG)) * L\_Basement\_Wall * H\_Basement\_Wall\_AG * (1\text{-}Framing\_Factor) * CDH * DUA) / (1000 * \eta Cool) * Adj_{Basementcool}$

Where:

R_Old_AG = *R_Value of foundation wall above grade*
= *Actual, if unknown assume 1.0*[608]

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[607] 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

[608] 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/ORNL_CON-295.pdf

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 insulation*[609]

24 = *converts days to hours*

CDH = *Cooling Degree Hours610*
= *dependent on location:*

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.*
=*0.75*[611]

ηCool = *Efficiency in SEER of Cooling Equipment.*
= *Actual. If unknown use*[612]*:*

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

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[609] ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

[610] 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/)

[611] 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.

[612] 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.

$Adj_{Basementcool}$ = *Adjustment to take into account prescriptive algorithms overclaiming savings*
= 80%[613]

$kWh_{heating}$ = *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 * ηHeat)*

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 * ηHeat)*

Where:

HDD = *Heating Degree Days*
= Dependent on location:[614]

Location	*Heating Degree Days (60°F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

3412 = *Converts kWh to BTU*

ηHeat = *Efficiency of Heating system, in COP. If not available, use*[615]*:*

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[613] As determined by Illinois Technical Resource Manual

[614] 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.

[615] 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

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 foundation[616]

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

H_Basement_Wall_BG = Height of basement wall below grade
$Adj_{Basementheat}$ *= Adjustment to account for prescriptive algorithms overclaiming savings*
= 60%[617]
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*

---

average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate

[616] Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

[617] As determined by the Illinois Technical Resource Manual.

Dependent on location as below:

Location	*Run Hours*
Wilmington, DE	*524* [618]
Baltimore, MD	*542* [619]
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*[620]
Baltimore, MD	*866*[621]
Washington, DC	*822*

HSPF = *Heating Seasonal Performance Factorof heating equipment*
= *Actual*

Illustrative examples – do not use as default assumption

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[618] 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)

[619] 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.

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 crawlspae. 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.

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

$kWh_{cooling} = ((1/2.25 - 1/(2.25 + 13)) * (20*2 + 25*2) * 3 * (1-0) * 7514 * 0.75) / (1{,}000 * 13) * 0.8$

$= 35$ kWh

$kWh_{heating} = ([((1/2.25 - 1/(2.25+13)) * (20*2 + 25*2) *3 * (1-0) * 3275 * 24) / (3412 * 2.26)] + [((1/(6.42+2.25) - 1/(6.42 + 2.25 + 13)) * (20*2+25*2) * 4 * (1-0) * 3275 * 24) / (3412 * 2.26)]) * 0.6$

$= 722$ kWh

$kWh_{ducts} = 524 * 36{,}000 * (1/13) * 0.05 / 1000 + 935 * 36{,}000 * (1/8) * 0.05 / 1{,}000$

$= 283$ kWh

$\Delta kWh = 35 + 722 + 283$

$= 1{,}040$ kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = kWh_{cooling} / Hours\_Cool * CF$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= 0.69 [622]

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*
= 0.66 [623]

Illustrative examples – do not use as default assumption

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[622] 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.

[623] 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.

For the house described above:

$\Delta kW = 35 / 524 * 0.69$

$= 0.046$ kW

Annual Fossil Fuel Savings Algorithm

If Natural Gas heating:

$\Delta therms = (therms_{AG} + therms_{BG}) * Adj_{Basement} + therms_{duct}$

Where:

$therms_{AG}$ = *Savings from insulation on walls or crawlspaces above grade*

$=((1/R\_Old\_AG – 1/(R\_Old\_AG + R\_Added)) * L\_Basement\_Wall * H\_Basement\_Wall\_AG * (1-Framing\_Factor) * HDD * 24) / (100{,}067 * \eta Heat)$

$therms_{BG}$ = *Savings from insulation on walls or crawlspaces below grade*

$= ((1/R\_Old\_BG – 1/(R\_Old\_BG + R\_Added)) * L\_Basement\_Wall * H\_Basement\_Wall\_BG * (1-Framing\_Factor) * HDD * 24) / (100{,}067 * \eta Heat)$

$therms_{duct}$ $= Hours\_Heat * BTU/Hour * AFUE * Duct\_Factor / 100{,}000$

Where:

Hours_heat = *Equivalent Full Load Heating Hours*

Location	EFLH
Wilmington, DE	848[624]
Baltimore, MD	620[625]
Washington, DC	528[626]

$\eta Heat$ = *Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*

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[624] 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

[625] 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.

[626] 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[627]*. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[628]*.*

Other factors as defined above

Illustrative examples – do not use as default assumption

For the house described above, but with a central furnace:

$\Delta therms = (therms_{AG} + therms_{BG}) * Adj_{Basement} + therms_{duct}$

$therms_{AG} = ((1/2.25 – 1/(2.25+13)) * (20*2+25*2) * 3 * (1-0) * 3275 * 24) / (100,067 * 0.66)$

$= 122\ therms$

$therms_{BG} = ((1/(2.25+6.42)-1/(2.25+6.42+13)) * (20*2+25*2) * 4 * (1-0) * 3275 * 24) / (100,067 * 0.66)$

$= 30\ therms$

$therms_{duct} = 848 * 100,000 * .84 * 0.05 / 100,000$

$= 36\ therms$

$\Delta therms = (122 + 30) *0.6 + 36$

$= 127$

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.

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[627] 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.

[628] 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.

Measure Life

The expected measure life is assumed to be 25 years.[629]

Operation and Maintenance Impacts

n/a

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[629] 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.[630]

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. 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

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[630] https://bpi.org/standards

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.

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [631]

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*
= *0.66* [632]

Annual Fossil Fuel Savings Algorithm

Fossil fuel savings are calculated by software model.

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 and air sealing work.

Measure Life

The measure life of air sealing is assumed to be 15 years[633]

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[631] 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.

[632] 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.

The measure life of insulation is assumed to be 25 years[634].

Operation and Maintenance Impacts

n/a

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[633] 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.

[634] 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.

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) standards[635].

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

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.

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[635] http://www.resnet.us/professional/standards

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)*
= 0.69[636]

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*
= 0.66[637]

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 years[638]
The measure life of insulation is assumed to be 25 years[639].

Operation and Maintenance Impacts

n/a

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[636] 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.

[637] 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.

[638] 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.

[639] 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.

Pool Pump End Use

Pool pump-two speed

Unique Measure Code: RS_PP_TOS_PPTWO_0711
Effective Date: June 2014
End Date: TBD

Measure Description

This measure describes the purchase of a two speed swimming pool pump capable of running at 50% speed and being run twice as many hours to move the same amount of water through the filter. 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, 1.36 kW electric pump operating 5.18 hours per day.

Definition of Efficient Condition

The efficient condition is an identically sized two speed pump operating at 50% speed (50% flow) for 10.36 hours per day.

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Two\ Speed}$$ [640]

Where:

kWh_{Base} = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= 707 kWh

$kWh_{Two\ Speed}$ = *typical consumption for an efficient two speed pump motor*
= 177 kWh

$$\Delta kWh = 707 - 177$$

$$= 530\ kWh$$

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[640] Based on INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [641]

Where:

kW_{Base} = *Connected load of baseline motor*

= *1.36 kW*

$kW_{Two\ Speed}$ = *Connected load of two speed motor = 0.171 kW*

CF_{SSP} = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*

= *0.20*[642]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather*

= *0.27*[643]

$$\Delta kW_{SSP} = (1.3-0.171) * 0.20$$

$$= 0.23 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3-0.171) * 0.27$$

$$= 0.31 \text{ kW}$$

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 motor[644].

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[641] 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

[642] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[643] Ibid.

Measure Life

The measure life is assumed to be 10 yrs[645].

Operation and Maintenance Impacts

n/a

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[644] Based on review of Lockheed Martin pump retail price data, July 2009.

[645] VEIC estimate.

Pool pump-variable speed

Unique Measure Code: RS_PP_TOS_PPVAR_0711
Effective Date: June 2014
End Date: TBD

Measure Description

This measure describes the purchase of a variable speed swimming pool pump capable of running at 40% speed and being run two and a half times as many hours to move the same amount of water through the filter. 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, 1.36 kW electric pump operating 5.18 hours per day.

Definition of Efficient Condition

The efficient condition is an identically sized variable speed pump operating at 40% flow for 13 hours per day.

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}$$ [646]

Where:

kWh_{Base} = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= 707 kWh

$kWh_{Variable\ Speed}$ = *typical consumption for an efficient variable speed pump motor*
= 113 kWh

$$\Delta kWh = 707 - 113$$

$$= 594\ kWh$$

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[646] Based on INTEGRATION OF DEMAND RESPONSE INTO TITLE 20 FOR RESIDENTIAL POOL PUMPS, SCE Design & Engineering; Phase1: Demand Response Potential DR 09.05.10 Report

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} – kW_{Two\ Speed}) * CF$$ [647]

Where:

kW_{Base} = *Connected load of baseline motor*
= *1.3 kW*
$kW_{Two\ Speed}$ = *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)*
= *0.20*[648]
CF_{PJM} = *PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.27*[649]

$$\Delta kW_{SSP} = (1.3\text{-}0.087) * 0.20$$

$$= 0.24\ kW$$

$$\Delta kW_{SSP} = (1.3\text{-}0.\ 087) * 0.27$$

$$= 0.34\ kW$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[647] 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

[648] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[649] Ibid.

The incremental cost for this time of sale measure is assumed to be $549 for a variable speed pool pump motor[650].

Measure Life

The measure life is assumed to be 10 yrs[651].

Operation and Maintenance Impacts

n/a

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[650] 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.

[651] VEIC estimate.

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.

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 kWh[652]

$Weighting_{Office}$ = Relative penetration of computers

= 41%[653]

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system

= 75.1 kWh[654]

$Weighting_{Ent}$ = Relative penetration of televisions

= 59%[655]

ISR = In service rate

= 89%[656]

ΔkWh = (31 * 41% + 75.1 * 59%) * 89%

= 50.7 kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = \Delta kWh / Hours * CF$

Where:

Hours = Annual hours when controlled standby loads are turned off
= 6,351[657]

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[652] 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.

[653] EmPower 2012 Residential Retrofit evaluation

[654] NYSERDA 2011, Advanced Power Strip Research Report

[655] EmPower 2012 Residential Retrofit evaluation

[656] EmPower EY6 QHEC Survey data.

CF = *Coincidence Factor*
= *0.8*[658]

ΔkW = (50.7/6,351) * 0.8
= 0.0064 kW

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 $18[659].

Measure Life

The measure life is assumed to be 4 years[660].

Operation and Maintenance Impacts

n/a

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[657] EmPower 2012 Residential Retrofit evaluation

[658] Ibid

[659] IILSAG 2015 Analysis

[660] 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.

Clothes Dryer

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 dryers[661]. ENERGY STAR provides criteria for both gas and electric clothes dryers. Note that this characterization only specifies gross savings. It is up to the individual program administrators and stakeholders to use proper net to gross ratios.

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

Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

Annual Energy Savings Algorithm

ΔkWh[662] $= kWh_{Base} - kWh_{ESTAR}$

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[661] 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

[662] 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

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*

Product Category[663]	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

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = *Energy Savings as calculated above*

Hours = *Annual run hours of clothes dryer.*

=*290 hours per year.*[664]

CF = *Summer Peak Coincidence Factor for measure*

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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 proceduce 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).

[663] Savings values come from Energy Star Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

[664] Assumes average of 56 minutes per cycle based on Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014

$= 2.9\%$[665]

Annual Fossil Fuel Savings Algorithm

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

$$\Delta MMBTU = MMBTU_{Base} - MMBTU_{STAR}$$

Where:

$MMBTU_{BASE}$ = Baseline MMBTU consumption per year
= As presented in the table below
$MMBTU_{ESTAR}$ = ENERGY STAR MMBTU consumption per year
=As presented in the table below

Product Category[666]	$MMBTU_{BASE}$	$MMBTU_{ESTAR}$	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.[667]

Measure Life

The expected measure life is assumed to be 12 years[668].

Operation and Maintenance Impacts

n/a

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[665] 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.

[666] Savings values come from Energy Star Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

[667] Energy Star Appliance Calculator, which cites "Cadmus Research on available models, July 2016."

[668] 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.

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	
Casement-Slider		10.4		11.4	

Note that this characterization only specifies gross savings. It is up to the individual program administrators and stakeholders to use proper net to gross ratios.

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.[669]

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[669] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

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.[670]

Annual Energy Savings Algorithm

ΔkWh[671] $= kWh_{Base} - kWh_{ESTAR}$

Where:

kWh_{BASE} = Baseline kWh consumption per year
= see table below for calculated values

kWh_{ESTAR} = ENERGY STAR kWh consumption per year
= see table below for calculated values

Location	Full-Load Cooling Hours	Savings (kWh/year)
Wlimington, DE	1,015	74.72
Baltimore, MD	1,050	77.30
Washington, DC	1,320	97.18

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = BTU/hour * (1/EERbase - 1/EERee))/1000 * CF$

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)*

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[670] http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf

[671] 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'

= *0.31* [672]

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*

= *0.3*[673]

Using deemed values above:

$\Delta kW_{ENERGY\ STAR\ SSP}$

= (8500 * (1/10.9 – 1/11.3)) / 1000 * 0.31

= 0.009 kW

$\Delta kW_{CEE\ TIER\ 1\ SSP}$

= (8500 * (1/10.9 – 1/11.8)) / 1000 * 0.31

= 0.018 kW

$\Delta kW_{ENERGY\ STAR\ PJM}$

= (8500 * (1/10.9 – 1/11.3)) / 1000 * 0.30

= 0.008 kW

$\Delta kW_{CEE\ TIER\ 1\ PJM}$

= (8500 * (1/10.9 – 1/11.8)) / 1000 * 0.30

= 0.018 kW

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 $20.

Measure Life

The measure life is assumed to be 9 years.[674]

---

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

[673] 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).

Operation and Maintenance Impacts

n/a

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[674] Based on Appliances Magazine – Market Research - The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013 (Dec. 2013).

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.[675] Note that this characterization only specifies gross savings. It is up to the individual program administrators and stakeholders to use proper net to gross ratios.

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 Algorithm[676]

$\Delta kWh = kWh_{base} - kWh_{eff}$

Where:

kWh_{base} = *Baseline unit energy consumption*
= *Assumed to be 69 kWh/year*[677]
kWh_{eff} = *Efficient unit energy consumption*
= *Assumed to be 25 kWh/year*[678] *for the ENERGY STAR +50%*

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[675] http://www.energystar.gov/sites/default/files/Final%20Version%203.0%20AV%20Program%20Requirements%20%28Rev%20Dec-2014%29.pdf

[676] Energy Savings from this measure are derived from Energy Star estimates. See ‘RPP Product Analysis 9-23-15.xlsx’

[677] 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.

Tier and 42.5 kWh/ year for the ENERGY STAR +15% Tier.

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0.0005$[679]

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[680].

Measure Life

The expected measure life is assumed to be 7 years.[681]

Operation and Maintenance Impacts

n/a

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[678] 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.

[679] Wattage difference between base and efficient sound bars when in sleep mode

[680] Incremental cost comes from Energy Star characterization. See ‘RPP Product Analysis 9-23-15.xlsx’

[681] ENERGY STAR assumes a 7-year useful life.

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. Note that this characterization only specifies gross savings. It is up to the individual program administrators and stakeholders to use proper net to gross ratios.

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 below[682].

- 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.

Annual Energy Savings Algorithm

ΔkWh[683] $= kWh_{Base} - kWh_{ESTAR}$

Where:

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[682] http://www.energystar.gov/sites/default/files/specs//private/Room_Air_Cleaners_Final_V1.2_Specification.pdf

[683] 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.

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

$\Delta kW = \Delta kWh / Hours * CF$

Where:

ΔkWh = Gross customer annual kWh savings for the measure
Hours = Average hours of use per year
= 5840 hours[684]
CF = Summer Peak Coincidence Factor for measure
= 0.67[685]

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.[686]

---

[684] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

[685] Assumes appliance use is equally likely at any hour of the day or night.

[686] ENERGY STAR Appliance Savings Calculator, which cites "EPA research on available models, 2012"

Measure Life

The measure life is assumed to be 9 years[687].

Operation and Maintenance Impacts

There are no operation and maintenance cost adjustments for this measure.[688]

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[687] 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

[688] 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.

ENERGY STAR Desktop Computer

Unique Measure Code(s): RS_PL_TOS_RPPSDC_xx18
Effective Date: xx 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.[689]

Annual Energy Savings Algorithm

$$\Delta kWh \quad = kWh_{base} - kWh_{eff}$$

Where:

kWh_{base} = *Baseline unit energy consumption*
= *Assumed to be 275 kWh/year*[690]
kWh_{eff} = *Efficient unit energy consumption*
= *Assumed to be 156 kWh/year*[691]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kWh \quad = kWh_{base} - kWh_{eff} \times CF$$

Where:

---

[689] https://www.energystar.gov/sites/default/files/specs//Version%206%201%20Computers%20Final%20Program%20Requirements.pd

[3] Baseline kWh is derived from the ENERGY STAR Office Equipment Calculator October 2016. Set to residential use and default medium performance level.

[4] Efficient kWh is derived from the ENERGY STAR Office Equipment Calculator. October 2016. Set to residential use and default medium performance level.

kWh_{base} = Baseline unit wattage
= Assumed to be 48.11[692]
kWh_{eff} = Efficient unit wattage
= Assumed to be 27.11[693]
CF = 38%[694]

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.[695]

Measure Life

The expected measure life is assumed to be 4 years.[696]

Operation and Maintenance Impacts

n/a

---

[692] Baseline wattage is for idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.

[693] Efficient wattage is idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.

[694] 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.

[695] ENERGY STAR Office Equipment Calculator.

[696] ENERGY STAR Office Equipment Calculator.

ENERGY STAR Laptop Computer

Unique Measure Code(s): RS_PL_TOS_RPPSLC_xx18
Effective Date: xx 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.[697]

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:

kWh_{base} = *Baseline unit energy consumption*
= *Assumed to be 53 kWh/year*[698]
kWh_{eff} = *Efficient unit energy consumption*
= *Assumed to be 31 kWh/year*[699]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff} \text{ x } CF$$

Where:

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[697] https://www.energystar.gov/sites/default/files/specs//Version%206%201%20Computers%20Final%20Program%20Requirements.pd

[3] Baseline kWh is derived from the ENERGY STAR Office Equipment Calculator October 2016. Set to residential use and default medium performance level.

[4] Efficient kWh is derived from the ENERGY STAR Office Equipment Calculator. October 2016. Set to residential use and default medium performance level.

kWh_{base} = *Baseline unit wattage*
= *Assumed to be 14.82*[700]

kWh_{eff} = *Efficient unit wattage*
= *Assumed to be 8.61*[701]

CF = *38%*[702]

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.[703]

Measure Life

The expected measure life is assumed to be 4 years.[704]

Operation and Maintenance Impacts

n/a

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[700] Baseline wattage is for idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.

[701] Efficient wattage is idle power (highest draw) from ENERGY STAR Office Equipment Calculator. Set to residential use and default medium performance level.

[702] Estimate based on idle hours as a percentage of all hours.

[703] 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..

[704] ENERGY STAR Office Equipment Calculator.

ENERGY STAR Computer Monitor

Unique Measure Code(s): RS_PL_TOS_RPPSCM_xx18
Effective Date: xx 2018
End Date: TBD

Measure Description

This measure relates to the upstream promotion of monitors meeting the ENERGY STAR Display Eligibility Criteria Version 7.1.

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 6.1 and used in a residential setting.[705]

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
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/year*[706]

---

[705] https://www.energystar.gov/sites/default/files/FINAL_Version7.1_Displays_ProgramRequirements.pdf

[3] Baseline 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.

[4] Efficient 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.

kWh_{eff} = Efficient unit energy consumption. . If screen size is known, see above.

Otherwise:

= Assumed to be 35 kWh/year[707]

Summer Coincident Peak kW Savings Algorithm

$\Delta kWh = kWh_{base} – kWh_{eff} \times CF$

Where:

kWh_{base} = Baseline unit wattage. If screen size is known:

Diagonal screen size	Conventional	ENERGY STAR
Less than 12 inches	6.6	5
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 20.3.11[708]

kWh_{eff} = Efficient unit wattage

= Assumed to be 17.2[709]

CF = 22%[710]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

---

[708] 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.

[709] 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.

[710] Estimate based on active hours as a percentage of all hours.

The incremental cost for this time of sale measure is $2.[711]

Measure Life

The expected measure life is assumed to be 7 years.[712]

Operation and Maintenance Impacts

n/a

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[711] Efficiency Vermont. Technical Reference User Manual (TRM). March 16, 2015. Ultra Efficient LCD Monitor measure. Rounded up from stated incremental cost of $1.80. .

[712] ENERGY STAR Office Equipment Calculator.

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.[713]

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:

kWh_{base} = *Baseline unit energy consumption varies by diagonal screen size.*[714]

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

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[713] https://www.energystar.gov/sites/default/files/FINAL%20Version%207.0%20Television%20Program%20Requirements%20%28Dec-2014%29_0.pdf

[714] ENERGY STAR Consumer Electronics Calculator. October 2016.

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
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%*[715]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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[715] Estimate based on On-mode hours per day (5 hours/day) as a percentage of all hours.

Incremental Cost

The incremental cost for this time of sale measure is $0.[716]

Measure Life

The expected measure life is assumed to be 6 years.[717]

Operation and Maintenance Impacts

n/a

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[716] 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. .

[717] ENERGY STAR Consumer Electronics Calculator.

COMMERCIAL & INDUSTRIAL MARKET SECTOR

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:

WattsBASE = Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.[718]

WattsEE = Actual Connected load of LED exit sign

HOURS = Average hours of use per year
= 8,760 [719]

ISR = In Service Rate or percentage of units rebated that get installed
= 1.00 [720]

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[718] 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.

[719] Assumes operation 24 hours per day, 365 days per year.

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.*
= *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* [721]

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta kWh / WHFe) * 0.00073.$$

Where:

0.7 = *Aspect ratio* [722]

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[720] 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.

[721] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[722] 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.

0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [723]
0.75 = *Assumed heating system efficiency* [724]

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure is $35.[725]

Measure Life

The measure life is assumed to be 5 years.[726]

Operation and Maintenance Impacts

	Baseline
	CFL
Replacement Cost	$8[727]
Component Life (years)	1.14[728]

The calculated net present value of the baseline replacement costs are presented below[729]:

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[723] 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).

[724] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[725] 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.

[726] 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.

[727] 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.

[728] 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.

[729] See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

Baseline	NPV of Baseline Replacement Costs
	2017
CFL	$26.92

Solid State Lighting (LED) Recessed Downlight Luminaire

Unique Measure Code: CI_LT_TOS_SSLDWN_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 specification[730]. 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 standard BR30-type incandescent downlight light bulb.

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

$$\Delta kWh = ((WattsBase - WattsEE) / 1,000) * ISR * HOURS * WHFe$$

Where:

WattsBase = Connected load of baseline lamp

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[730] ENERGY STAR specification can be viewed here: https://www.energystar.gov/sites/default/files/asset/document/Luminaires%20V2%200%20Final.pdf

= Find the equivalent baseline wattage based on the LED initial lumen output from the table below[731]; if unknown assume 65W[732] pre-2020 or 23W after January 1st, 2020.

Lower Lumen Range	Upper Lumen Range	2018-2019 WattsBase	2020+ WattsBase[733]
400	449	40	*
450	499	45	*
500	649	50	*
650	1419	65	*
1420	1789	75	*
1790	2049	90	*
2050	2579	100	*
2580	3299	120	*
3300	4270	150	150
**For lamps and fixtures < 3300 lumens, the baseline after 2020 should be calculated as WattsBase = (LumensEE / 45)*[734]			

LumensEE = Lumen output of efficient lamp.
= Actual. If unknown assume 650 lumens[735].
WattsEE = Connected load of efficient lamp
= Actual. If unknown assume 9.2W [736]
ISR = In Service Rate or percentage of units rebated that get installed.
= 1.0[737]

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[731] 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

[732] Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc. Adjusted by ratio of lm/w in ENERGY STAR V2.1 compared to ENERGY STAR V1.2 specification.

[733] Different jurisdictions may have different implementation start dates for the 2020 baseline shift.

[734] 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/UMPChapter21-residential-lighting-evaluation-protocol.pdf

[735] Calculated using the minimum lumen output for a BR lamp of 650 lumens.

[736] 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.

[737] 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.

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.*[738]

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.*
= *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.

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[738] 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.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75

= (-ΔkWh / WFHe) * 0.00073

Where:

0.7 = *Aspect ratio* [739]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [740]

0.75 = *Assumed heating system efficiency* [741]

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 lifecycle NPV incremental costs, based on an average value for a wide range of applicable LED lamps, are provided below for time of sale[742]. 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.

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[739] 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.

[740] 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).

[741] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[742] 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.

However, measure life is not to exceed 15 years[743].The fixture life should be assumed to be 25,000 hours for separable luminaires and 50,000 hours for inseparable luminaires[744].

Operation and Maintenance Impacts

The leveled baseline replacement cost over the lifetime of the SSL is presented below.[745] 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[746]

The calculated net present value of the baseline replacement costs is $210 for downlights featuring inseparable components and $118 for downlights with replaceable parts[747].

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[743] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[744] 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.

[745] 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=pLlMjfvz.

[746] 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.

[747] See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

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
= 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.[748]

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

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[748] 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.

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((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 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.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.
= (-ΔkWh / WHFe) * 0.00073.

Where:

0.7 = Aspect ratio [749]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating [750]
0.75 = Assumed heating system efficiency [751]

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[749] 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.

[750] 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).

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.[752]

Measure Life

The measure life is assumed to be 15 years.[753]

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 lamp[754].

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[751] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[752] 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.

[753] 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

[754] See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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

$$\Delta kWh = kWconnected * HOURS * SVGe * ISR * WHFe$$

Where:

kWconnected = 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.[755]

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

= 0.28 [756]

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[755] 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.

ISR = *In Service Rate or percentage of units rebated that get installed*
= 1.00 [757]

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

$$\Delta kW = kWconnected * SVGd * ISR * WHFd * CF$$

Where:

SVGd = *Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.*
= 0.14 [758]

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.

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[756] 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.

[757] 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.

[758] 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.

For example, a 400W connected load being controlled in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 * 0.14 * 1.00 * 1.32 * 0.69$$

$$= 0.051 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta kWh / WHFe) * 0.00073.$$

Where:

0.7 = Aspect ratio [759]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [760]

0.75 = Assumed heating system efficiency [761]

Annual Water Savings Algorithm

n/a

Incremental Cost

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 utrasonic capabilities. [762]

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[759] 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.

[760] 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).

[761] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[762] 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

Measure Life

The measure life is assumed to be 10 years.[763]

Operation and Maintenance Impacts

n/a

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labor rates. Calculations, data and sources are available at http://www.neep.org/file/5548/download?token=pLlMjfvz.

[763] 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

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

$$\Delta kWh = kWconnected \times HOURS \times SVG \times ISR \times WHFe$$

Where:

kWconnected = 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.[764]

SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.
= 0.28 [765]

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[764] 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.

ISR = *In Service Rate or percentage of units rebated that get installed = 1.00*[766]

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.

Summary Coincident Peak kW Savings Algorithm[767]

$$\Delta kW = kWconnected \times SVG \times ISR \times WHFd \times CF$$

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 conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

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[765] 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.

[766] 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.

[767] 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.

$\Delta kW = 0.4 * 0.28 * 1.00 * 1.32 * 0.69$

$= 0.10$ kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$
$= (-\Delta kWh / WHFe) * 0.00073.$

Where:

0.7 = Aspect ratio [768]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating [769]
0.75 = Assumed heating system efficiency [770]

Annual Water Savings Algorithm

n/a

Incremental Cost

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.[771]

Measure Life

The measure life is assumed to be 10 years.[772]

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[768] 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.

[769] 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).

[770] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[771] 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.

Operation and Maintenance Impacts

n/a

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[772] 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

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 jurisdiction: Maryland Building Performance Standards (2015 International Energy Conservation Code); Title 16, Chapter 76 of the Delaware Code (2012 International Energy Conservation Code); and District of Columbia Construction Codes Supplement of 2013 (2012 International Energy Conservation Code). Because lighting power density requirements differ by jurisdiction, this measure entry presents two different baseline conditions to be used in each of the three relevant jurisdictions. For completeness, the lighting power density requirements for both the Building Area Method and the Space-by-Space Method are presented.[773]

Definition of Efficient Condition

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[773] 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.

The efficient condition assumes lighting systems that achieve lighting power densities below the maximum lighting power densities required by the relevant jurisdictional energy codes as described above. Actual lighting power densities should be determined on a site-specific basis.

Annual Energy Savings Algorithm[774]

$$\Delta kWh = ((LPDBASE - LPDEE) / 1000) * AREA * HOURS * WHFe$$

Where:

LPDBASE = Baseline lighting power density for building or space type (W/ft^2). See tables below for values by jurisdiction and method.[775]

LPDEE = Efficient lighting power density (W/ft^2)
= Actual calculated

AREA = Building or space area (ft^2)

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.[776]

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.

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[774] 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.

[775] Codes changes affecting lighting power density requirements are likely to occur for at least some jurisdictions between June 2017 and June 2018; however, revised requirements are not yet known. Any code updated will be reflected in the June 2018-May 2019 TRM (V8).

[776] 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.

Building Area Method Baseline LPD Requirements by Jurisdiction[777]

	Lighting Power Density (W/ft^2)	
Building Area Type	**Washington, D.C. and Delaware**	**Maryland**
Automotive Facility	0.90	0.80
Convention Center	1.20	1.01
Court House	1.20	1.01
Dining: Bar Lounge/Leisure	1.30	1.01
Dining: Cafeteria/Fast Food	1.40	0.90
Dining: Family	1.60	0.95
Dormitory	1.00	0.57
Exercise Center	1.00	0.84
Fire Station	0.80	0.67
Gymnasium	1.10	0.94
Healthcare-Clinic	1.00	0.90
Hospital	1.20	1.05
Hotel	1.00	0.87
Library	1.30	1.19
Manufacturing Facility	1.30	1.17
Motel	1.00	0.87
Motion Picture Theatre	1.20	0.76
Multi-Family	0.70	0.51
Museum	1.10	1.02
Office	0.90	0.82
Parking Garage	0.30	0.21
Penitentiary	1.00	0.81
Performing Arts Theatre	1.60	1.39

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[777] IECC 2015, Table C405.4.2 (1); IECC 2012, Table C405.5.2 (1). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2010, Table 9.5.1. As the IECC 2012 requirements are less stringent they are presented here.

	Lighting Power Density (W/ft^2)	
Building Area Type	**Washington, D.C. and Delaware**	**Maryland**
Police Station	1.00	0.87
Post Office	1.10	0.87
Religious Building	1.30	1.00
Retail	1.40	1.26
School/University	1.20	0.87
Sports Arena	1.10	0.91
Town Hall	1.10	0.89
Transportation	1.00	0.70
Warehouse	0.60	0.66
Workshop	1.40	1.19

Space-by-Space Method Baseline LPD Requirements for Washington, D.C. and Delaware[778]

Common Space-By-Space Types	Lighting Power Density (W/ft^2)
Atrium - First 40 feet in height	0.03 per ft. ht.
Atrium - Above 40 feet in height	0.02 per ft. ht.
Audience/seating area - Permanent	
For auditorium	0.9
For performing arts theater	2.6
For motion picture theater	1.2
Classroom/lecture/training	1.3
Conference/meeting/multipurpose	1.2
Corridor/transition	0.7

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[778] IECC 2012, Table C405.5.2(2). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2010, Table 9.5.1. As the IECC 2012 requirements are less stringent they are presented here.

Dining Area	
Bar/lounge/leisure dining	1.4
Family dining area	1.4
Dressing/fitting room performing arts theater	1.1
Electrical/mechanical	1.1
Food preparation	1.2
Laboratory for classrooms	1.3
Laboratory for medical/industrial/research	1.8
Lobby	1.1
Lobby for performing arts theater	3.3
Lobby for motion picture theater	1.0
Locker room	0.8
Lounge recreation	0.8
Office – enclosed	1.1
Office - open plan	1.0
Restroom	1.0
Sales area	1.6
Stairway	0.7
Storage	0.8
Workshop	1.6
Courthouse/police station/penitentiary	
Courtroom	1.9
Confinement cells	1.1
Judge chambers	1.3
Penitentiary audience seating	0.5
Penitentiary classroom	1.3
Penitentiary dining	1.1
Building Specific Space-By-Space Types	**Lighting Power Density (W/ft^2)**
Automobile – service/repair	0.7

Bank/office - banking activity area	1.5
Dormitory living quarters	1.1
Gymnasium/fitness center	
Fitness area	0.9
Gymnasium audience/seating	0.4
Playing area	1.4
Healthcare clinic/hospital	
Corridor/transition	1.0
Exam/treatment	1.7
Emergency	2.7
Public and staff lounge	0.8
Medical supplies	1.4
Nursery	0.9
Nurse station	1.0
Physical therapy	0.9
Patient Room	0.7
Pharmacy	1.2
Radiology/imaging	1.3
Operating room	2.2
Recovery	1.2
Lounge/recreation	0.8
Laundry - washing	0.6
Hotel	
Dining area	1.3
Guest rooms	1.1
Hotel lobby	2.1
Highway lodging dining	1.2
Highway lodging guest rooms	1.1
Library	
Stacks	1.7

Card file and cataloging	1.1
Reading area	1.2
Manufacturing	
Corridor/transition	0.4
Detailed manufacturing	1.3
Equipment room	1.0
Extra high bay (>50-foot floor-ceiling height)	1.1
High bay (25-50-foot floor-ceiling height)	1.2
Low bay (<25-foot floor-ceiling height)	1.2
Museum	
General exhibition	1.0
Restoration	1.7
Parking garage – garage areas	0.2
Convention center	
Exhibit space	1.5
Audience/seating area	0.9
Fire stations	
Engine room	0.8
Sleeping quarters	0.3
Post office – sorting area	0.9
Religious building	
Fellowship hall	0.6
Audience seating	2.4
Worship pulpit/choir	2.4
Retail	
Dressing/fitting area	0.9
Mall concourse	1.6
Sales area	1.6
Sports arena	

Audience seating	0.4
Court sports area - Class 4	0.7
Court sports area - Class 3	1.2
Court sports area - Class 2	1.9
Court sports area - Class 1	3.0
Ring sports arena	2.7
Transportation	
Airport/train/bus baggage area	1.0
Airport concourse	0.6
Terminal - ticket counter	1.5
Warehouse	
Fine material storage	1.4
Medium/bulky material	0.6

Space-by-Space Method Baseline LPD Requirements for Maryland[779]

Common Space-By-Space Types	Lighting Power Density (W/ft^2)
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	2.43
In a religious building	1.53

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[779] IECC 2015, Table C405.4.2 (2).

In a sports arena	0.43
Otherwise	0.43
Banking activity area	1.01
Breakroom (See Lounge/Breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	1.34
Otherwise	1.24
Conference/meeting/multipurpose room	1.23
Copy/print room	0.72
Corridor	
In a facility for the visually impaired (and not used primarily by staff)	0.92
In a hospital	0.79
In a manufacturing facility	0.41
Otherwise	0.66
Courtroom	1.72
Computer room	1.71
Dining area	
In a penitentiary	0.96
In a facility for the visually impaired (and not used primarily by staff)	1.9
In bar/lounge or leisure dining	1.07
In cafeteria or fast food dining	0.65
In family dining	0.89
Otherwise	0.65
Electrical/mechanical room	0.95
Emergency vehicle garage	0.56
Food preparation area	1.21
Guest room	0.47
Laboratory	
In or as a classroom	1.43

Otherwise	1.81
Laundry/washing area	0.6
Loading dock, interior	0.47
Lobby	
In a facility for the visually impaired (and not used primarily by the staff)	1.8
For an elevator	0.64
In a hotel	1.06
In a motion picture theater	0.59
In a performing arts theater	2.0
Otherwise	0.9
Locker room	0.75
Lounge/breakroom	
In a healthcare facility	0.92
Otherwise	0.73
Office	
Enclosed	1.11
Open plan	0.98
Parking area, interior	0.19
Pharmacy area	1.68
Restroom	
In a facility for the visually impaired (and not used primarily by the staff)	1.21
Otherwise	0.98
Sales area	1.59
Seating area, general	0.54
Stairway (See space containing stairway)	
Stairwell	0.69
Storage room	0.63
Vehicular maintenance area	0.67
Workshop	1.59

Building Type Specific Space Types	Lighting Power Density (W/ft^2)
Facility for the visually impaired	
In a chapel (and not used primarily by the staff)	2.21
In a recreation room (and not used primarily by the staff)	2.41
Automotive (See Vehicular Maintenance Area above)	
Convention Center – exhibit space	1.45
Dormitory – living quarters	0.38
Fire Station – sleeping quarters	0.22
Gymnasium/fitness center	
In an exercise area	0.72
In a playing area	1.2
Healthcare facility	
In an exam/treatment room	1.66
In an imaging room	1.51
In a medical supply room	0.74
In a nursery	0.88
In a nurse’s station	0.71
In an operating room	2.48
In a patient room	0.62
In a physical therapy room	0.91
In a recovery room	1.15
Library	
In a reading area	1.06
In the stacks	1.71
Manufacturing facility	
In a detailed manufacturing facility	1.29
In an equipment room	0.74
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)	1.23
In a low bay area (less than 25’ floor-to-ceiling height)	1.19
Museum	
In a general exhibition area	1.05
In a restoration room	1.02
Performing arts theater – dressing room	0.61
Post Office – Sorting Area	0.94
Religious buildings	
In a fellowship hall	0.64
In a worship/pulpit/choir area	1.53
Retail facilities	
In a dressing/fitting room	0.71
In a mall concourse	1.1
Sports arena – playing area	
For a Class I facility	3.68
For a Class II facility	2.4
For a Class III facility	1.8
For a Class IV facility	1.2
Transportation facility	
In a baggage/carousel area	0.53
In an airport concourse	0.36
At a terminal ticket counter	0.8
Warehouse – storage area	
For medium to bulky, palletized items	0.58
For smaller, hand-carried items	0.95

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft^2 conditoned office building with gas heat in in DE using the Building Area Method with an LPDEE of 0.75:

ΔkWh = ((0.9 - 0.75) / 1000) * 15,000 * 2,969 * 1.10

= 7,348 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((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 ft^2 conditoned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75 and estimating PJM summer peak coincidence:

ΔkWh = ((0.9 - 0.75) / 1000) * 15,000 * 1.32 * 0.69

= 2.05 kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75
= (-ΔkWh / WHFe) * 0.00073

Where:

0.7 = Aspect ratio[780]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating[781]
0.75 = Assumed heating system efficiency[782]

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft^2 conditoned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75:

$$\Delta kWh = (-7{,}348 / 1.10) * 0.00073$$

$$= -4.88 \text{ MMBTU}$$

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

The measure life is assumed to be 15 years.[783]

Operation and Maintenance Impacts

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[780] 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.

[781] 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).

[782] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[783] 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.

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.

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 List[784].

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS$$

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

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[784] DesignLights Consortium Qualified Products List <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

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 Wattage[785]

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

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[785] 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
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.

= If annual operating hours are unknown, assume 3,338 [786]*.*
Otherwise, use site specific annual operating hours information.[787]

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\Delta kWh = ((288 – 172) / 1000) * 3,338$$

$$= 387 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * CF$$

Where:

CF = Summer Peak Coincidence Factor for measure
= 0 [788]

Illustrative examples – do not use as default assumption

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

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[786] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[787] 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.

[788] It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

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. [789]

Measure Description	Time of Sale / New	Early Replacement
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 50,000[790] hours. However, measure life is not to exceed 15 years[791].

Operation and Maintenance Impacts[792]

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[789] 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.

[790] 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.

[791] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[792] 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.

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[793].

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[793] See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

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 List[794].

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

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[794] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

= 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.[795]

ISR = In Service Rate or percentage of units rebated that get installed
= 1.00 [796]

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.
= 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.

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[795] 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.

[796] 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.

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 [797]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating [798]
0.75 = Assumed heating system efficiency [799]

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.[800]

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[797] 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.

[798] 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).

[799] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[800] 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 50,000[801] hours. However, measure life is not to exceed 15 years[802].

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 $32.50 per lamp for time of sale and $31.63 per lamp for early replacement[803].

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[801] Minimum DesignLights Consortium requirement is 50,000 hours for high bay fixtures. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[802] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[803] See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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.[804]

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

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 Wattage[805]

Measure Category	Baseline Description	WattsBASE	Efficient Description	WattsEE

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[804] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[805] 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.

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 Appendix D. For exterior lamps, assume 3,338 [806]*.Otherwise, use site specific annual operating hours information.*[807]

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

= 1.00 [808]

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.

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[806] Efficiency Vermont Technical Reference User Manual 2015-87C, March 2015; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[807] 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.

[808] 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.

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 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, 0* [809]

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 1.0 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00105$$

Where:

1.0 = *Aspect ratio* [810]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [811]
0.75 = *Assumed heating system efficiency* [812]

Annual Water Savings Algorithm

n/a

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[809] It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

[810] 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.

[811] 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).

[812] 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.[813]

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. If rated life is unknown, then assume 50,000[814] hours. However, measure life is not to exceed 15 years[815].

Operation and Maintenance Impacts[816]

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.

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[813] Measure and baseline costs were calculated using bulb cost and specification data gathered from vendor websites in Q1 2018.

[814] 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/>

[815] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[816] 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.

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

The efficient condition is defined as an LED high-bay luminaire. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List[817].

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

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[817] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

= If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D.[818] *Otherwise, use site specific annual operating hours information.*[819]

ISR = In Service Rate or percentage of units rebated that get installed = 1.00 [820]

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.
= 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

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[818] 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.

[819] 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.

[820] 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.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.
= (-ΔkWh / WHFe) * 0.00073.

Where:

0.7 = Aspect ratio [821]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating [822]
0.75 = Assumed heating system efficiency [823]

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 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. [824]

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[821] 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.

[822] 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).

[823] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[824] 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 ($/klm)	Retrofit ($/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. If rated life is unknown, then assume 50,000[825] hours. However, measure life is not to exceed 15 years[826].

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 replacement[827]

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[825] 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/>

[826] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[827] See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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 List[828].

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR$$

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.

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[828] DesignLights Consortium Qualified Products List <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

Parking Garage or Canopy Fixture Baseline and Efficient Wattage[829]

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*
= If annual operating hours are unknown, assume 3,338 for canopy applications and 8,760 for parking garage applications[830]*. Otherwise, use site specific annual operating hours information.*[831]

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[829] 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
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.

[830] 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.

ISR *= In Service Rate or percentage of units rebated that get installed*
= 1.00 [832]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta kWh = ((288 - 162) / 1000) * 8{,}760 * 1.00$$

$$= 1104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

CF *= Summer Peak Coincidence Factor for measure*
= 0 for canopy applications and 1.0 for parking garage applications [833]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta kW = ((288 - 162) / 1000) * 1.00 * 1.00$$

$$= 0.13 \text{ kW}$$

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[831] 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.

[832] 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.

[833] 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.

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 needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook. [834]

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 50,000[835] hours. However, measure life is not to exceed 15 years[836].

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[834] 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.

[835] 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/>

[836] 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[837]

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 [838].

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[837] 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.

[838] See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.

ENERGY STAR Integrated Screw Based SSL (LED) Lamp – Commercial

Unique Measure Code: CI_LT_TOS_SSLDWN_0518, CI_LT_EREP_SSLDWN_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

Time of Sale: The baseline wattage is assumed to be an incandescent or EISA complaint (where applicable) bulb installed in a screw-base socket.[839] 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: http://1.usa.gov/1QJFLgT.

Annual Energy Savings Algorithm

Time of Sale:

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

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

Early Replacement[840]:

ΔkWh for remaining life of existing unit:

$$\Delta kWh = ((\text{WattsExist} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR} * \text{WHFe}$$

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

$$\Delta kWh = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR} * \text{WHFe}$$

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 appropiate year column in the table below relative to the end of the in-situ lamp useful life.

	Lower Lumen Range	Upper Lumen Range	2018-2019 WattsBase	2020+ WattsBase[841]
Omnidirectional, Medium Screw Base Lamps (A, BT, P, PS, S or T) (†, ◊see exceptions below)	250	309	25	*
	310	749	29	*
	750	1049	43	*
	1050	1489	53	*
	1490	2600	72	*
	2601	3300	150	*
	3301	3999	200	200
	4000	6000	300	300

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[840] 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.

[841] Different jurisdictions may have different implementation start dates for the 2020 baseline shift.

	Lower Lumen Range	Upper Lumen Range	2018-2019 WattsBase	2020+ WattsBase[841]
†S Shape <=749 lumens and T Shape <=749 lumens or T>10" length)	250	309	25	*
	310	749	40	*
Decorative, Medium Screw Base (G Shape) (‡see exceptions below)	250	309	25	*
	310	749	29	*
	750	1049	43	*
	1050	1300	53	*
‡G16-1/2, G25, G30 <=499 lumens	250	309	25	*
	310	349	25	*
	350	499	40	*
‡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	29	*
	500	699	29	*
*B, BA, CA, and F <=499 lumens	70	89	10	*
	90	149	15	*
	150	299	25	*
	300	309	40	*
	310	499	40	*
Omnidirectional, Intermediate Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	25	*
	310	749	40	*
†S Shape that have a first number symbol <= 12.5 and T	250	309	25	*

	Lower Lumen Range	Upper Lumen Range	2018-2019 WattsBase	2020+ WattsBase[841]
Shape lamps with first number symbol <= 8 and nominal overall length <12"	310	749	40	*
Decorative, Intermediate Screw Base (G Shape) (‡see exceptions below)	250	309	25	*
	310	349	25	*
	350	499	40	*
‡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	40	*
Omnidirectional, Candelabra Screw Base Lamps (A, BT, P, PS, S or T) (†see exceptions below)	250	309	25	*
	310	749	40	*
	750	1049	60	*
†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	25	*
	350	499	40	*
	500	574	60	*
‡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	40	*

	Lower Lumen Range	Upper Lumen Range	2018-2019 WattsBase	2020+ WattsBase[841]
	500	699	60	*
Directional, Medium Screw Base, w/diameter <=2.25"	400	449	40	*
	450	499	45	*
	500	649	50	*
	650	1199	65	*
Directional, Medium Screw Base, R, PAR, ER, BR, BPAR or similar bulb shapes w/ diameter >2.5 " (**see exceptions below)	640	739	40	*
	740	849	45	*
	850	1179	50	*
	1180	1419	65	*
	1420	1789	75	*
	1790	2049	90	*
	2050	2579	100	*
	2580	3300	120	*
	3301	3429	120	120
	3430	4270	150	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	40	*
	630	719	45	*
	720	999	50	*
	1000	1199	65	*
	1200	1519	75	*
	1520	1729	90	*
	1730	2189	100	*
	2190	2899	120	*
	2900	3300	120	*
	3301	3850	150	150
**ER30, BR30, BR40, or ER40	400	449	40	*
	450	499	45	*
	500	649-1179	50	*
**BR30, BR40, or ER40	650	1419	65	*
**R20	400	449	40	*
	450	719	45	*
**All reflector lamps below lumen ranges specified above	200	299	20	*
	300	399-639	30	*
◊Rough service,	250	309	25	*

	Lower Lumen Range	Upper Lumen Range	2018-2019 WattsBase	2020+ WattsBase[841]
shatter resistant, 3-way incandescent, and vibration service	310	749	40	*
	750	1049	60	*
	1050	1489	75	*
	1490	2600	100	*
	2601	3300	150	*
	3301	3999	200	200
	4000	6000	300	300
**For lamps and fixtures < 3300 lumens, the baseline after 2020 should be calculated as WattsBase = (LumensEE / 45)*[842]				

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.*[843]

ISR = *In Service Rate or percentage of units rebated that are installed and operational*

= *1.00.*[844]

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.*

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[842] 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/UMPChapter21-residential-lighting-evaluation-protocol.pdf

[843] 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.

[844] 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.

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:

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

Early Replacement[845]:

ΔkW for remaining life of existing unit:

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

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

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

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.*

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[845] 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.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

Where:

0.7 = Aspect ratio. [846]
0.003413 = Constant to convert kWh to MMBTU.
0.23 = Fraction of lighting heat that contributes to space heating. [847]
0.75 = Assumed heating system efficiency. [848]

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.[849]

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.

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[846] 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.

[847] 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).

[848] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[849] Cost assumptions are adapted from analysis provided by Apex Analytics LLC in April 2018.

If rated life is unknown, then assume 15,000[850] hours. However, measure life is not to exceed 15 years[851].

Remaining Useful Life

RULhour = *Remaining Useful Life calculated in hours.*
= *EULexist – (HOURS * Age)*
NOTE:
If RULhour < 1000, set RULhour = 0.
If RULhour > HOURS, set RULhour = HOURS.

RUL = *Remaining Useful Life calculated in years, rounded.*
= *RULhour / HOURS (with any fraction rounded)*

Where:

EULexist = *Actual expected useful life of in-situ lamp. If useful life is unknown, then reference the table below.*

	Expected Useful Life (Hours)[852]
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
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

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[850] Eneryg 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>

[851] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[852] California DEER's Remote Ex-Ante Database Interface (READI) v.2.4.7

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 = *EULexist – (HOU * Age)*
= 3500 – (1201 * 1.25)
= 1,999
RULyear = *RULhour / HOU (with any fraction rounded)*
= 1999 / 1201 *(with any fraction rounded)*
= 1.66 (*with any fraction rounded)*
= **2**

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. The key assumptions used in this calculation are documented below[853]:

	Price of Lamps that are EISA 2012-2014 Compliant	Price of Lamps that are EISA 2020 Compliant[854]
Replacement Cost Unknown	$1.70	$3.12
Replacement Cost, Globe	$1.74	$6.56
Replacement Cost, Reflector	$4.27	$6.52
Replacement Cost, A Lamp	$1.62	$6.00
Replacement Cost, Candelabra	$1.14	$5.20
Component Life (hours)	1,000	6,000-10,000, depending on lamp style

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[853] Baseline incandescent lamp cost assumptions are adapted from analysis provided by Apex Analytics LLC in April 2018.

[854] Different jurisdictions may have different implementation start dates for the 2020 baseline shift.

The calculated default net present values of lamp replacements over the measure life for time of sale and replacement applications in the years 2018-2019 and once EISA 2020 is in effect are presented below[855].

Bulb Type	Time of Sale 2018-2019	Replacement 2018-2019	Time of Sale 2020+[854]	Replacement 2020+[854]
Unknown	$18.77	$12.58	$3.14	$4.27
Globe	$24.71	$18.43	$12.35	$13.05
Reflector	$36.31	$24.23	$5.74	$7.79
A Lamp	$23.37	$17.37	$11.44	$12.09
Candelabra	$19.62	$14.72	$10.13	$10.70

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[855] 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.

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 Consortium[856] (DLC) qualified 4-pin LED lamp[857].

Annual Energy Savings Algorithm

ΔkWh = ((WattsBase - WattsEE) /1000) * HOURS * ISR * WHFe

Where:

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[858]
760	934	13
935	1349	18
1350	1834	26
1835	2549	32
2550	3199	42

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[856] https://www.designlights.org/

[857] DLC qualification is not required for LED lamps below 675 lumens.

[858] DOE and NREL TRM template for LED pin-base CFL replacements with input from stakeholders, “Tech to Utilities Draft Template_LED4Pin_20170919.xlxs”

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.*[859]

ISR = *In Service Rate or percentage of units rebated that are installed and operational*
= *1.00.* [860]

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

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

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*

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[859] 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.

[860] 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.

= 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.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

Where:

0.7 = Aspect ratio. [861]

0.003413 = Constant to convert kWh to MMBTU.

0.23 = Fraction of lighting heat that contributes to space heating. [862]

0.75 = Assumed heating system efficiency. [863]

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.

Lower Lumen Range	Upper Lumen Range	Time of Sale Incremental Cost[864]
760	934	$15
935	1349	$13
1350	1834	$24

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[861] 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.

[862] 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).

[863] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[864] 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.

Lower Lumen Range	Upper Lumen Range	Time of Sale Incremental Cost[864]
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 50,000[865] hours. However, measure life is not to exceed 15 years[866].

Operation and Maintenance Impacts[867]

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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[865] Minimum DesignLights Consortium requirement. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[866] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[867] 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.

LED Refrigerated Case Lighting

Unique Measure Code(s): CI_LT_TOS_LEDRCL_0518, CI_LT_RF_LEDRCL_0518
Effective Date: May 2018
End Date: TBD

Measure Description

This measure relates to the installation of LED luminaries 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 Luminaries” 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

ΔkWh = (WattsPerLFBASE – WattsPerLFEE) / 1000 * LF * HOURS * WHFe.

Where:

WattsPerLFBASE = Connected wattage per linear foot of the baseline fixtures; see table below for default values.[868]
WattsPerLFEE = Connected wattage per linear foot of the LED fixtures.[869]
= Actual installed. If actual installed wattage is unknown, see table below for default values.

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[868] Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

[869] Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

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.[870]
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.[871]

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.[872]
CF = Summer Peak Coincidence Factor for measure

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[870] 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.

[871] 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.

[872] 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.

= 0.96 (lighting in Grocery).[873]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[874]

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 50,000[875] hours. However, measure life is not to exceed 15 years[876].

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 applications[877].

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

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[873] 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.

[874] Navigant. May 2014. Incremental Cost Study Phase Three Final Report. Prepared for NEEP Regional Evaluation, Measurement & Verification Forum

[875] Minimum DesignLights Consortium requirement. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[876] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[877] See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.

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 List[878].

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS.$$

Where:

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.*[879]

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
PAR38	500	1000	52.5
	1000	4000	108.7
Metal Halide	4000	15000[880]	205.0
Metal Halide	15000	20000	288
Metal Halide	20000	30000	460

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[878] DesignLights Consortium Qualified Products List <https://www.designlights.org/qpl>

[879] 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.

[880] 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.

WattsEE = Actual Connected load of the LED luminaire.

HOURS = Average hours of use per year.

= If annual operating hours are unknown, assume 3,338 [881]*. Otherwise, use site specific annual operating hours information.*[882]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * CF.$$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0. [883]

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 needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook. [884]

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[881] Efficiency Vermont TRM User Manual No. 2014-85b; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[882] 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.

[883] It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

[884] 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 / 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 50,000[885] hours. However, measure life is not to exceed 15 years[886].

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.[887]

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[885] Minimum DesignLights Consortium requirement. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[886] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[887] 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.

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
WattsEE = Wattage of actual lamp installed; see table below

Default Lamp Wattage Assumptions[888]

Lamp/Ballast System	Per Lamp Wattage (W)
Assumed Baseline 32W T8 IS NLO	28.2

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[888] 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.

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.[889]

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.*
= HVAC type is unknown for midstream measures. WHFe = 1.0.[890]

Summary 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

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[889] 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.

[890] 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.

Note: Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75 * HTM.
= (-ΔkWh / WHFe) * 0.00073.

Where:

0.7 = Aspect ratio. [891]
0.003413 = Constant to convert kWh to MMBTU.
0.23 = Fraction of lighting heat that contributes to space. heating [892]
0.75 = Assumed heating system efficiency. [893]
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[894]

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs associated with linear fluorescent lamp replacement are $2 per lamp[895].

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.

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[891] 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.

[892] 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).

[893] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[894] 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.

[895] This is the current midstream program buydown for Baltimore Gas and Electric: https://bgesmartenergy.com/business/instant-lighting-discounts (3/9/2018).

If rated life is unknown, then assume 24,000 hours.[896] However, measure life is not to exceed 15 years[897].

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.

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[896] 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.

[897] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

LED Four-Foot Linear Replacement Lamps

Unique Measure Code(s): CI_LT_RF_LEDTUBE_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:[898]

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 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.

All of the EmPOWER Maryland Utilities, no longer provide incentives for linear LED lamps with an internal driver connected directly to the line voltage (commonly referred to as "Type B.") This is due to the wide variety of installation characteristics of these types of lamps and the inherent safety concerns with these being powered directly from 120 – 277 voltage.

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[898] Underwriters Laboratories (UL) Standard 1598

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 List[899].

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.*

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 Assumptions[900]

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[901]	32	13	19

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[899] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[900] 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.

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.*[902]

ISR = *In Service Rate or percentage of units rebated that get installed.*
= *1.00.* [903]

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.*
= *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.*

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[901] The T5 wattage with ballast losses was sourced from: https://www.xcelenergy.com/staticfiles/xe/Marketing/MN-Bus-Lighting-Input-Wattage-Guide.pdf

[902] 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.

[903] 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.

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.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.
= (-ΔkWh / WHFe) * 0.00073.

Where:

0.7 = *Aspect ratio.* [904]
0.003413 = *Constant to convert kWh to MMBTU.*
0.23 = *Fraction of lighting heat that contributes to space. heating* [905]
0.75 = *Assumed heating system efficiency.* [906]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs (equipment and labor) LED linear replacement lamps are as follows:[907]

Type A: $22.67 per LED replacement lamp.
Type C: $22.67 per LED replacement lamp, $15.07 for the external driver.

Measure Life

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[904] 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.

[905] 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).

[906] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[907] 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).

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 50,000[908] hours. However, measure life is not to exceed 15 years[909].

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.[910]

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[908] 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.

[909] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[910] 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.

Networked Lighting Controls

Unique Measure Code(s): CI_LT_RF_NLC_0619, CI_LT_NC_NLC_0619
Effective Date: June 2019
End Date: TBD

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

The efficient condition is LLLC lighting that is controlled by a network system. Sensors must include occupancy and photo sensors, and the system must be able to dim or turn off individual fixtures based on local occupancy and light levels.

Annual Energy Savings Algorithm

$$\Delta kWh = kW_{connected} * HOURS * (SVG – BLC) * ISR * WHF_e$$

Where:

$kW_{connected}$ = *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.[911]

SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using the default value based on building type from the table below.[912]

Building Type	Control Savings Factor (Energy)[913]
Assembly	0.23
Manufacturing	0.30
Office	0.63
School	0.28
Restaurant	0.47
Retail	0.44
Warehouse	0.82
Other	0.47

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	0.28

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[911] 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.

[912] Networked Lighting Control energy savings come from DLC report: Energy Savings from Networked Lighting Control (NLC) Systems, 2017.

[913] 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.

code[914]	
New Construction – Occupancy sensors not required by code	0.00

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 WHFe = WHFd = 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 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.

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[914] See local appropriate code documentation for occupancy sensor requirements.

$$\Delta MMBTU = (-\Delta kWh / WHF_e) * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00105$$

Where:

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [915]

0.80 = Assumed heating system thermal efficiency [916]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for the network-controlled systems is assumed to be $2.06 per square foot.[917] 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.

Measure Life

The measure life is assumed to be 10 years.[918]

Operation and Maintenance Impacts

n/a

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[915] 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).

[916] Typical heating system thermal efficiency of 80%, consistent with minimum current federal standards for fossil fuel-fired systems.

[917] 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

[918] 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

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 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 2012 International Energy Conservation Code (IECC 2012) and the 2015 International Energy Conservation Code (IECC 2015) (see table “Baseline Efficiencies by System Type and Unit Capacity” below)[919] or federal standards where more stringent than local energy codes. Note that due to federal standards scheduled to take effect on January 1, 2018, baseline requirements for some equipment classes differ over time.

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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[919] Commercial energy code baseline requirements for Washington, D.C. and Delaware are currently consistent with IECC 2012 (Delaware currently uses ASHRAE 90.1-2010, but the HVAC system requirements are consistent with IECC 2012), whereas Maryland’s baseline requirements are consistent with IECC 2015.

Baseline Efficiencies by System Type and Unit Capacity

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (IECC 2012 or Federal Standard) [920]	Baseline Condition (IECC 2015 or Federal Standard)
Air Conditioners, Air Cooled			
<65,000 BTU/h	Split system	13.0 SEER	13.0 SEER
	Single package	14.0 SEER	14.0 SEER
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	11.3 EER 12.9 IEER	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	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	10.0 EER 11.6 IEER
≥760,000 BTU/h	Split system and single package	9.7 EER 9.8 IEER	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	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	12.1 EER 13.9 IEER
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	12.5 EER 12.7 IEER	12.5 EER 13.9 IEER
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	12.4 EER 12.6 IEER	12.4 EER 13.6 IEER
≥760,000 BTU/h	Split system and single package	12.0 EER 12.4 IEER	12.2 EER 13.5 IEER

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[920] Whichever requires a higher level of baseline efficiency IECC or Federal Standards.

The federal standards are provided by Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards for Small, Large, and Very Large Air-Cooled Commercial Package Air Conditioning and Heating Equipment and Commercial Warm Air Furnaces; Final Rule, 81 Fed. Reg. 10 (January 15, 2016). Federal Register: The Daily Journal of the United States.

The federal standards do present EER requirements. The baseline requirements in the table are estimated based on the ratio of the EER and IEER values from IECC 2015 for the corresponding equipment category.

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (IECC 2012 or Federal Standard) [920]	Baseline Condition (IECC 2015 or Federal Standard)
Air Conditioners, Evaporatively Cooled			
<65,000 BTU/h	Split system and single package	12.1 EER 12.3 IEER	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	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	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	11.9 EER 12.1 IEER
≥760,000 BTU/h	Split system and single package	11.7 EER 11.9 IEER	11.7 EER 11.9 IEER
Heat Pumps, Air Cooled[921]			
<65,000 BTU/h	Split System	14.0 SEER 8.2 HSPF	14.0 SEER 8.2 HSPF
	Single Package	14.0 SEER 8.0 HSPF	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	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	10.6 EER 11.6 IEER 3.2 COP
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	9.5 EER 10.6 IEER 3.2 COP	9.5 EER 10.6 IEER 3.2 COP

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[921] Heating mode efficiencies for heat pumps >=65,000 BTU/h are provided at the 47°F db/43° wb outdoor air rating condition.

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards)[922]
Packaged Terminal Air Conditioners[923,924]		
All Capacities	New Construction (Standard Size)[925]	14.0 – (0.300 * Cap/1000) EER
All Capacities	Replacement (Non-Standard Size)	10.9 – (0.213 * Cap/1000) EER
Packaged Terminal Heat Pumps[926,927]		
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)

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[922] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.96 (2016).

[923] 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.

[924] “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.

[925] Federal standard as presented for this equipment type is effective January 1, 2017. This standard is consistent with IECC 2015 and ASHRAE 90.1-2013 requirements and is recommended as a consistent regional baseline.

[926] 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.

[927] “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.

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:

$\Delta kWh = (BTU/h_{COOL}/1000) * ((1/SEERBASE) – (1/SEEREE)) * HOURS_{COOL}$.

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 Replacement[928]:

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

ΔkWh for remaining life of existing unit:
$= (BTU/h_{COOL}/1000) * ((1/SEEREXIST) – (1/SEEREE)) * HOURS_{COOL}$.

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):
$= (BTU/h_{COOL}/1000) * ((1/SEERBASE) – (1/SEEREE)) * HOURS_{COOL}$.

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[928] 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 (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:

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:

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) – (1/EEREE)) * HOURS_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * HOURS_{HEAT.}$

Early Replacement[929]:

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:

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEEREXIST) – (1/SEEREE)) * HOURS_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPFEXIST) – (1/HSPFEE)) * HOURS_{HEAT.}$

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

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEERBASE) – (1/SEEREE)) * HOURS_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPFBASE) – (1/HSPFEE)) * HOURS_{HEAT.}$

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

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[929] 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:

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

$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEEREXIST) – (1/IEEREE)) * HOURS_{COOL.}$

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEXIST) – (1/COPEE)) * HOURS_{HEAT.}$

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

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

$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEERBASE) – (1/IEEREE)) * HOURS_{COOL.}$

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * HOURS_{HEAT.}$

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

ΔkWh for remaining life of existing unit:

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

$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EEREXIST) – (1/EEREE)) * HOURS_{COOL.}$

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEXIST) – (1/COPEE)) * HOURS_{HEAT}$

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

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

$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EERBASE) – (1/EEREE)) * HOURS_{COOL.}$

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * HOURS_{HEAT.}$

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.*

SEEREE = SEER of efficient unit.
= Actual Installed.
SEERBASE = SEER of baseline unit.
= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.
SEEREXIST = SEER of the existing unit.
= Actual.
HSPFEE = HSPF of efficient unit.
= Actual Installed.
HSPFBASE = HSPF of baseline unit.
= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.
HSPFEXIST = HSPF of the existing unit.
= Actual.
IEEREE = IEER of efficient unit.
= Actual Installed.
IEERBASE = IEER of baseline unit.
= Based on IECC 2012 or IECC 2015 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 2012 or IECC 2015 for the installed capacity. See table above.
COPEXIST = COP of the existing unit.
= Actual.
EERBASE = EER of baseline unit.
= Based on IECC 2012 or 2015 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.*[930]
= 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.

$HOURS_{HEAT}$ = *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.

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

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

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*
= 0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.[931]

CF_{UPeak} = *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.[932]

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[930] 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."

[931] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

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.[933] Prescribed values vary depending on the current building code, the date of installation, and whether the baseline condition is time of sale or early replacement.[934]

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[932] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

[933] 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.

[934] 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

Time of Sale Air-Cooled Unitary Air Conditioners Incremental Costs ($/ton)[935]

Size Category (Cooling Capacity)	Subcategory	Incremental Cost ($/ton)		
		Installation Before January 1, 2018		Installations on or After January 1, 2018
		Baseline Condition (IECC 2012)	Baseline Condition (IECC 2015)	Baseline Condition (Federal Standards)
<65,000 BTU/h	Split system	$179	$179	Unchanged
	Single package	$243	$ 156	Unchanged
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	$287	$287	$395
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	$191	$191	$151
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	$43	$43	$50
≥760,000 BTU/h	Split system and single package	$40	$40	Unchanged

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[935] 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 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

Time of Sale Air-Source Unitary Heat Pumps Incremental Costs ($/ton)[936]

Size Category (Cooling Capacity)	Subcategory	Incremental Cost ($/ton)		
		Before January 1, 2018		On or After January 1, 2018
		Baseline Condition (IECC 2012)	Baseline Condition (IECC 2015)	Baseline Condition (Federal Standards)
<65,000 BTU/h	Split System	$236	$118	Unchanged
	Single Package	$184	$92	Unchanged
≥65,000 BTU/h and <135,000 BTU/h	Split system and single package	$25	$25	$0
≥135,000 BTU/h and <240,000 BTU/h	Split system and single package	$13	$13	$0
≥240,000 BTU/h and <760,000 BTU/h	Split system and single package	$30	$30	$0

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[936] 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 >=135,000 BTU/h. For equipment >=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 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

Early Replacement Air-Cooled Unitary Air Conditioners Costs and Deferred Replacement Credits ($/ton)[937]

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

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[937] 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

Air-Source Unitary Heat Pumps Early Retirement Costs and Deferred Replacement Credits ($/ton)[938]

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.[939]

Operation and Maintenance Impacts

n/a

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[938] 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 >=135,000 BTU/h. For equipment >=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 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

[939] 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.

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.

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.[940] 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.

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[940] 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 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.

Baseline Window AC Efficiency[941]

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[942]	All	13	11.2
Packaged Air Conditioners[943]	All	14	11.8
Packaged Air Source Heat Pumps[944]	All	14	11.8

Baseline Heating System Efficiency

Equipment Type	Efficiency Metric	Efficiency

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[941] Federal standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

[942] Federal Standard as of January 1, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

[943] Ibid.

[944] Ibid

Equipment Type	Efficiency Metric	Efficiency
Gas Boiler[945]	AFUE	82%
Air Source Heat Pump – Split System[946]	HSPF	8.2
Air Source Heat Pump - Packaged	HSPF	8.0
Electric Resistance[947]	HSPF	3.41

Annual Energy Savings Algorithm

$\Delta kWh_{total} = \Delta kWh_{cool} + \Delta kWh_{heat.}$

$\Delta kWh_{cool} = CCAP \text{ x } (1/SEER_{base} – 1/SEER_{ee}) \text{ x } EFLH_{cool}.$

ΔkWh_{heat} [948] $= HCAP \text{ x } (ELECHEAT/HSPF_{base} – 1/HSPF_{ee}) \text{ x } EFLH_{heat}.$

Where:

CCAP = Cooling capacity of DMSHP unit, in kBTU/hr.

$SEER_{base}$ = SEER of baseline unit. If unknown, use 9.8[949]*.*

$SEER_{ee}$ = 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.[950]

$HSPF_{ee}$ = 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

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[945] Federal Standards for gas boilers

[946] Federal standards for air source heat pumps

[947] Electric heat has a COP of 1.0. Converted into HSPF units this is approximately 3.41.

[948] 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.

[949] Federal standard for typical window AC sizes with louvered sides.

[950] If unknown, assume the baseline is a gas furnace, with no electrical savings

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*[951].

EER_{ee} =*EER of actual DMSHP. If unknown, use ENERGY STAR 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.[952]

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.[953]

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = HCAP \times EFLH_{heat} / AFUE / 1,000$$

Where:

$EFLH_{heat}$ = *Full load hours for heating equipment. See table above.*

$AFUE$ = *AFUE of baseline equipment. If unknown use 82%.*[954]

Incremental Cost

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[951] Federal standard for typical window AC sizes with louvered sides.

[952] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011

[953] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

[954] Federal standard for gas boilers.

The full installed cost of the ductless mini-split system is shown below.[955]

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[956]	$170/unit
Gas furnace[957]	$1,606/unit
Electric Baseboard[958]	$0[959]

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 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.[960]

Operation and Maintenance Impacts

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[955] Navigant, Inc. Incremental Cost Study Phase 2. January 16, 2013. Table 16.

[956] Energy Star Calculator. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)

[957] 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

[958] If existing case is electric resistance heat, assume project replaces existing functional baseboard.

[959] 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.

[960] 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.

n/a

Variable Frequency Drive (VFD) for HVAC

Unique Measure Code(s): CI_MO_RF_VFDRIVE_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 Algorithm[961]

HVAC Fan Applications

$$\Delta kWh = \Delta kWh_{FAN} * (1 + IE_{ENERGY})$$

$$\Delta kWh_{FAN} = kWh_{BASE} - kWh_{RETRO}$$

$$kWh_{BASE} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}}\right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{BASE})$$

$$kWh_{RET} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}}\right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{RET})$$

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[961] 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.

Where:

ΔkWh_{FAN} = *Fan-only annual energy savings.*

IE_{ENERGY}= *HVAC interactive effects factor for energy*

= *Assume 0%.*[962]

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%.*

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%

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[962] 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.

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

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

$$\Delta kW = \Delta kW_{FAN} * (1 + IE_{DEMAND}).$$
$$\Delta kW_{FAN} = \Delta kW_{BASE} - \Delta kW_{RETRO.}$$
$$\Delta kW_{BASE} = (0.746 * HP * LF / \eta_{MOTOR}) * PLR_{BASE,\ PEAK.}$$
$$\Delta kW_{RETRO} = (0.746 * HP * LF / \eta_{MOTOR}) * PLR_{RETRO,\ PEAK.}$$

Where:

ΔkW_{FAN} = *Fan-only annual demand savings (kW).*
IE_{DEMAND} = *HVAC interactive effects factor for demand.*
= *If unknown, assume 0%.*[963]
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%).*

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[963] 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.

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
= 0.55. [964]

VFD Operating Hours by Application and Building Type ($RHRS_{BASE}$)[965]

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
Gymnasium	2,586	1,348	5,376
Hospitals	7,674	3,180	8,760*
Hospitals / Health Care	7,666	3,177	8,760*

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[964] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives - Pumps.

[965] 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.

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
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
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 Factors[966]

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

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.[967]

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[966] 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.

[967] 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

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.[968]

Operation and Maintenance Impacts

n/a

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[968] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

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: For Washington, D.C. and Delaware, the baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2012 (IECC 2012), Table C403.2.3(7). For Maryland, the baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2015 (IECC 2015), Table C403.2.3(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

For Washington, D.C. and Delaware, the efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2012 (IECC 2012), Table C403.2.3(7). For Maryland, the efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2015 (IECC 2015), Table C403.2.3(7).

Annual Energy Savings Algorithm

Time of Sale and New Construction:

$$\Delta kWh = TONS * (IPLVbase - IPLVee) * HOURS.$$

Early Replacement[969]:

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

$$= TONS * (IPLVexist - IPLVee) * HOURS.$$

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

$$= TONS * (IPLVbase - IPLVee) * HOURS.$$

Where:

TONS = Total installed capacity of the water chilling package[tons].
= Actual Installed.
IPLVexist = Integrated Part Load Value (IPLV)[970] of the existing equipment [kW/ton].
IPLVbase = Integrated Part Load Value (IPLV) of the new baseline equipment [kW/ton].
= Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below.[971]
IPLVee = 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.

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[969] 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.

[970] Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

[971] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages and International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Packages - Efficiency Requirements

Summer Coincident Peak kW Savings Algorithm

Time of Sale and New Construction:

ΔkW = TONS * (Full_Loadbase - Full_Loadee) * CF.

Early replacement:

ΔkW for remaining life of existing unit (i.e., measure life less the age of the existing equipment):
= TONS * (Full_Loadexist - Full_Loadee) * CF.

ΔkW for remaining measure life (i.e., measure life less the remaining life of existing unit):
= 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 below[972]

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.[973]

CF_{SSP} *= Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).*
= 0.923.[974]

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[972] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages and International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Packages - Efficiency Requirements

[973] 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.

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

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs for time of sale chillers are shown in the tables below for time of sale and new construction scenarios.[975] 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) for Washington, D.C. and Delaware

Capacity (Tons)	Baseline EER	Efficient EER			
		9.9	10.2	10.52	10.7
50	9.562	$137	$259	$350	$411
100	9.562	$69	$129	$175	$206
150	9.562	$46	$86	$117	$137
200	9.562	$34	$65	$88	$103
400	9.562	$17	$32	$44	$51

Air-Cooled Chiller Incremental Costs ($/Ton) for Maryland

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

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[975] 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.

Capacity (Tons)	Baseline EER	Efficient EER			
		9.9	10.2	10.52	10.7
150	10.1	N/A	$18	$49	$69
200	10.1	N/A	$14	$ 37	$52
400	10.1	N/A	$7	$ 18	$26

Water-Cooled Scroll/Screw Chiller Incremental Costs ($/Ton) for Washington, D.C. and Delaware

Capacity (Tons)	Baseline kW/ton	Efficient kW/ton			
		0.72	0.68	0.64	0.60
50	0.78	$311	$518	N/A	N/A
100	0.775	$143	$246	N/A	N/A
150	0.68	N/A	N/A	N/A	N/A
200	0.68	N/A	N/A	$52	$104
400	0.62	N/A	N/A	N/A	$13

Water-Cooled Scroll/Screw Chiller Incremental Costs ($/Ton) for Maryland

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) for Washington, D.C. and Delaware

Capacity (Tons)	Baseline kW/ton	Efficient kW/ton		
		0.6	0.58	0.54
100	0.634	$88	$140	$244
150	0.634	$59	$93	$162
200	0.634	$44	$70	$122
300	0.576	N/A	N/A	$31
600	0.57	N/A	N/A	$13

Water-Cooled Centrifugal Chiller Incremental Costs ($/Ton) for Maryland

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 years[976].

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency for Washington, D.C. and Delaware[977]

Equipment Type	Size Category	Units	Path A[a]		Path B[a]	
			Full Load	IPLV	Full Load	IPLV
Air-Cooled Chillers	<150 tons	EER	≥9.562	≥12.500	NA	NA
	≥150 tons	EER	≥9.562	≥12.750	NA	NA
Water Cooled, Electrically Operated, Positive Displacement	<75 tons	kW/ton	≤0.780	≤0.630	≤0.800	≤0.600
	≥75 tons and <150 tons	kW/ton	≤0.775	≤0.615	≤0.790	≤0.586
	≥150 tons and <300 tons	kW/ton	≤0.680	≤0.580	≤0.718	≤0.540
	≥300 tons	kW/ton	≤0.620	≤0.540	≤0.639	≤0.490
Water Cooled, Electrically Operated, Centrifugal	<150 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥150 tons and <300 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥300 tons and <600 tons	kW/ton	≤0.576	≤0.549	≤0.600	≤0.400
	≥600 tons	kW/ton	≤0.570	≤0.539	≤0.590	≤0.400

a. Compliance with IECC 2012 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.

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[976] 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"

[977] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages.

Time of Sale Baseline Equipment Efficiency for Maryland[978]

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 2015 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.

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[978] Baseline efficiencies based on International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Package - Efficiency Requirements.

Full Load Cooling Hours by Location and Building Type (HOURS)[979]

Space and/or Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Education - Community College	737	725	743	677	867	714	899
Education - Secondary School	366	360	369	336	431	355	446
Education - University	809	796	816	743	952	784	987
Health/Medical - Hospital	1,557	1,533	1,570	1,430	1,832	1,510	1,900
Health/Medical - Nursing Home	596	586	601	547	701	578	727
Lodging - Hotel	1,787	1,758	1,801	1,641	2,102	1,732	2,180
Manufacturing – Bio Tech/High Tech	804	791	810	738	946	779	981
Office - Large	598	589	603	549	704	580	730
Office - Small	554	545	559	509	652	537	676
Retail - Multistory Large	920	906	928	845	1,083	892	1,123

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[979] 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.

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

$$\Delta MMBTU = CAP * HOURS * (1/EFF_{base} - 1/EFF_{ee}) / 1{,}000{,}000.$$

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.[980]

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 below[981] *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.

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 years[982].

Operation and Maintenance Impacts

n/a

Reference Tables

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[980] 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.

[981] Baseline efficiencies based on the Energy Independence and Security Act of 2007 and the International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[982] Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

Time of Sale Baseline Equipment Efficiency[983]

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency
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	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 Costs[984]

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
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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[983] Baseline efficiencies based on current federal standards: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf.

[984] 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 BTUh/h sources Incremental Cost values are derived from the Commercial Packaged TSD.
https://www.regulations.gov/document?D=EERE-2013-BT-STD-0030-0083

Full Load Heating Hours by Location and Building Type (HOURS$_{HEAT}$)[985]

Space and/or Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	1,114	1,150	1,114	1,168	1,064	1,079	1,040
Education - Community College	713	736	713	747	681	691	666
Education - Primary School	668	689	668	700	638	647	623
Education - Relocatable Classroom	647	668	647	679	618	627	604
Education - Secondary School	719	742	719	754	687	697	671
Education - University	530	546	530	555	506	513	494
Grocery	984	1,015	984	1,031	939	953	918
Health/Medical - Hospital	214	221	214	224	204	207	200
Health/Medical - Nursing Home	932	962	932	977	890	903	870
Lodging - Hotel	2,242	2,313	2,242	2,350	2,140	2,172	2,092
Manufacturing – Bio Tech/High Tech	146	151	146	153	139	141	136
Manufacturing – 1 Shift/Light Industrial	585	603	585	613	558	567	546
Multi-Family (Common Areas)	256	264	256	268	244	248	239
Office - Large	221	228	221	231	211	214	206
Office - Small	440	454	440	461	420	426	411
Restaurant - Fast-Food	1,226	1,265	1,226	1,285	1,170	1,188	1,144
Restaurant - Sit-Down	1,131	1,167	1,131	1,185	1,079	1,096	1,055
Retail - Multistory Large	591	609	591	619	564	572	551
Retail - Single-Story Large	739	762	739	774	705	716	689
Retail - Small	622	642	623	652	594	603	581
Storage - Conditioned	854	881	854	895	815	828	797
Warehouse - Refrigerated	342	353	343	359	327	332	320

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[985] 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.

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 Algorithm[986]

ΔkWh = 733 kWh.[987]

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.19 kW.[988]

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = CAP * HOURS * ((1/AFUE_{base}) - (1/AFUE_{ee})) / 1{,}000{,}000.$$

Where:

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[986] Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

[987] 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.

[988] Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.

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.*[989]

$AFUE_{base}$ = *Annual Fuel Utilization Efficiency of the baseline equipment.*
= *For time of sale: 0.80.*[990]

$AFUE_{ee}$ = *Annual Fuel Utilization Efficiency of the efficient equipment.*
= *Actual Installed.*

1,000,000 = *BTU/MMBTU unit conversion factor.*

Annual Water Savings Algorithm

n/a

Incremental Cost

The time of sale incremental cost for this time of sale measure is provided below.[991]

Efficiency of Furnace (AFUE)	Incremental Cost
90%	$392
92%	$429
95%	$537
98%	$659

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[989] 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.

[990] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(4) Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements and International Energy Conservation Code 2015, Table C403.2.3(4) Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters, Minimum Efficiency Requirements. Review of GAMA shipment data indicates a more suitable market baseline is 80% AFUE. Further, pending federal standards, 10 CFR 430.32(e) ()(1) ()(i), scheduled to take effect in November 2015 will raise the baseline for non-weatherized gas furnaces to 80% AFUE. The baseline unit is non-condensing.

[991] 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.

Measure Life

The measure life is assumed to be 18 years[992].

Operation and Maintenance Impacts

n/a

Reference Tables

Full Load Heating Hours by Location and Building Type ($\text{HOURS}_{\text{HEAT}}$)[993]

Space and/or Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	1,114	1,150	1,114	1,168	1,064	1,079	1,040
Education - Community College	713	736	713	747	681	691	666
Education - Primary School	668	689	668	700	638	647	623
Education - Relocatable Classroom	647	668	647	679	618	627	604
Education - Secondary School	719	742	719	754	687	697	671
Education - University	530	546	530	555	506	513	494
Grocery	984	1,015	984	1,031	939	953	918
Health/Medical - Hospital	214	221	214	224	204	207	200
Health/Medical - Nursing Home	932	962	932	977	890	903	870
Lodging - Hotel	2,242	2,313	2,242	2,350	2,140	2,172	2,092
Manufacturing – Bio Tech/High Tech	146	151	146	153	139	141	136
Manufacturing – 1 Shift/Light Industrial	585	603	585	613	558	567	546
Multi-Family (Common Areas)	256	264	256	268	244	248	239
Office - Large	221	228	221	231	211	214	206
Office - Small	440	454	440	461	420	426	411
Restaurant - Fast-Food	1,226	1,265	1,226	1,285	1,170	1,188	1,144
Restaurant - Sit-Down	1,131	1,167	1,131	1,185	1,079	1,096	1,055

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[992] 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"

[993] 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.

Space and/or Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Retail - Multistory Large	591	609	591	619	564	572	551
Retail - Single-Story Large	739	762	739	774	705	716	689
Retail - Small	622	642	623	652	594	603	581
Storage - Conditioned	854	881	854	895	815	828	797
Warehouse - Refrigerated	342	353	343	359	327	332	320

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.[994]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0 \text{ kW}.$$[995]

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[994] 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.

[995] Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

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 Costs[996]

HVAC System Capacity (Tons)	Incremental Cost
5	$943
15	$1,510
25	$2,077
40	$2,927
70	$4,628

Measure Life

The measure life is assumed to be 10 years[997].

Operation and Maintenance Impacts

n/a

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[996] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

[997] General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

Reference Tables

Savings Factors[998]

Savings Factors (kWh/ton)	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	26	22	25	29	25	27	25
Big Box Retail	58	50	57	66	57	62	56
Fast Food	37	32	37	42	36	40	36
Full Service Restaurant	29	25	29	34	29	32	28
Light Industrial	24	21	23	27	23	25	23
Primary School	40	34	39	45	39	43	39
Small Office	58	50	57	66	57	62	56
Small Retail	58	50	57	66	57	62	56
Religious	6	5	6	6	6	6	6
Warehouse	2	2	2	2	2	2	2
Other	58	50	57	66	57	62	56

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[998] 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.[999] 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

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

$$\Delta kWh = CCAP \text{ x } EFLH \text{ x } 1/SEER_{pre} \text{ x } \%\_impr.$$

Where:

CCAP = Cooling capacity of existing AC unit, in kBTU/hr.

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[999] California Public Utilities Commission. *HVAC Impact Evaluation Final Report*. January 28, 2014.

$SEER_{pre}$ = *SEER of actual unit, before the tune-up. If testing is not done on the baseline condition, use the nameplate SEER.*

EFLH = *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.*

%_impr = *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.*[1000]

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.*[1001]

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.*[1002]

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.*[1003]

[1000] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[1001] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[1002] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011

[1003] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011

Annual Fossil Fuel Savings Algorithm

n/a

Incremental Cost

Use the actual cost of the tune-up. If this is unknown, use a default of \$35/ton[1004].

Measure Life

The measure life for an AC tune-up is 5 years.[1005]

Operation and Maintenance Impacts

n/a

[1004] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 4.0 Final February 24 2015

[1005] 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.

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 2012 International Energy Conservation Code (IECC 2012) and the 2015 International Energy Conservation Code (IECC 2015).

Definition of Efficient Condition

The efficient condition is a smart thermostat that has earned ENERGY STAR certification[1006] or has the following product requirements[1007]:

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.

[1006] ENERGY STAR’s qualified products list for smart thermostats: https://data.energystar.gov/dataset/ENERGY-STAR-Certified-Connected-Thermostats/7p2p-wkbf

[1007] 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

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 ≤ ± 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

As smart thermostats are control technologies, when possible, heating and cooling savings should be calculated based on data from installed thermostats.[1008] 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.

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

$\Delta kWh_{cooling} = CCAP \times HOURS_{cool} \times 1/SEER \times ElecCool\_Saving\_\%$

$\Delta kWh_{heating} = HCAP_{elec} \times HOURS_{heat} \times 1/HSPF \times ElecHeat\_Saving\_\%$

$\Delta MMBTU = HCAP_{fuel} \times HOURS_{heat} \times 1/AFUE \times FuelHeat\_Saving\_\%$

[1008] 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.

Where:

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

	Baseline Technology	
Fuel and Function	Manual Thermostat[1009]	Programmable Thermostat[1010]
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

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 $154[1011] and the incremental cost for a retrofit

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[1009] 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

[1010] 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/

[1011] 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-replacement is assumed to be $208.[1012] Installation labor cost of $50 for labor should be added to the assumed incremental cost.

Measure Life

The measure life is assumed to be 7.5 years.[1013]

Operation and Maintenance Impacts

n/a

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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.

[1012] 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

[1013] 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

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 Construction[1014]: 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-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

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[1014] 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.

with code minimum efficiency for the remainder of the measure life.[1015] 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

Equipment Type	Capacity (Btu/h)	Code Minimum[1016]	Minimum Qualifying Efficiency[1017]
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	12.3 IEER 11.0 EER	14.2 IEER 11.3 EER
	135,000 ≤ Btu/h < 240,000	11.8 IEER 10.6 EER	13.7 IEER 10.9 EER
	≥ 240,000 Btu/h	10.6 IEER 9.5 EER	12.5 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	47°F db / 43°F wb outdoor Air	3.4 COP

[1015] 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.

[1016] ASHRAE 90.1 2013, Table 6.8.1-10.

[1017] CEE Tier 1 efficiencies. https://library.cee1.org/system/files/library/7559/Appendix_A_2016-18_CEE_ComACHP_UnitarySpec.pdf

Equipment Type	Capacity (Btu/h)	Code Minimum[1016]	Minimum Qualifying Efficiency[1017]
	(cooling capacity)	3.3 COP_H	
		17°F db / 15°F wb outdoor Air 2.25 COP_H	2.4 COP
	$\geq$ 135,000 Btu/h (cooling capacity)	47°F db / 43°F wb outdoor Air 3.2 COP_H	3.2 COP
		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	14.0 EER
	65,000 $\leq$ Btu/h < 135,000 (cooling capacity)	12.0 EER	14.0 EER
	$\geq$ 135,000 Btu/h (cooling capacity)	10.0 EER	12.0 EER
VRF – water cooled (heating mode)	< 135,000 Btu/h (cooling capacity)	4.2 COP_H	4.6 COP
	$\geq$ 135,000 Btu/h (cooling capacity)	3.9 COP_H	4.3 EER

Annual Energy Savings Algorithm

$$\Delta kWh_{total} = \Delta kWh_{cool} + \Delta kWh_{heat}.$$

$$\Delta kWh_{cool} = (BTU/h_{cool}/1000) * (1/CEF_{base} - 1/CEF_{ee}) * EFLH_{cool}.$$

$$\Delta kWh_{heat}{}^{1018} = (ELECHEAT * BTU/h_{heat} / HEF_{base} - BTU/h_{heat} / HEF_{ee}) / HU * EFLH_{heat}.$$

[1018] 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.

Where:

BTU/h_{cool} = Cooling capacity of VRF system, in BTU/hr.

1000 = Btu/hr to kBTU/hr conversion factor

CEF_{base} = Baseline Cooling Efficiency Factor. SEER if $BTU/h_{cool} < 65{,}000$ Btu/hr. IEER if $BTU/h_{cool} \geq 65{,}000$ Btu/hr.

- *If early replacement, CEF_{base} will be the efficiency of the existing unit for the Remaining Useful Life (RUL). At the end of its RUL, CEF_{base} becomes code minimum. New Construction and Time of Sale always use code minimum.*
- *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.*

CEF_{ee} = Cooling Efficiency Factor of installed VRF system. SEER if $BTU/h_{cool} < 65{,}000$ Btu/hr. IEER if $BTU/h_{cool} \geq 65{,}000$ Btu/hr.

- *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.

ELECHEAT = 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.*[1019]
CF_{SSP} = *Summer System Peak Coincidence Factor*
= *0.588 for units <135 kBtu/h and 0.874 for units ≥135 kBtu/h.*[1020]

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBtu = BTU/h_{heat} \times EFLH_{heat} / TE / 1,000,000$$

Where:

[1019] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011

[1020] C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

$EFLH_{heat}$ = *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 ≤2,500 kBtu/h and 82% for units with a heating capacity >2,500 kBtu/h.*[1021]

Incremental Cost

The incremental costs are assumed to be as follows.

Installation Type	Baseline	Capacity	Incremental Cost ($/ton) [1022]
Replace on Burnout	Replacing Packaged Unitary Unit w/VAV	All	$540
	Replacing Single Zone Packaged AC + Gas Furnace	All	$835
	Replacing Single Zone Packaged Air-Source Heat Pump	All	$860
Early Replacement	Replacing Packaged Unitary Unit	All	$737[1023]
New Construction	Code-Minimum VRF	All	Attain quote from contractor on cost of installed VRF vs. a code compliant VRF

[1021] Federal standard for gas-fired hot water boilers, based on ASHRAE 90.1 2007, table 6.8.1F, matched by IECC 2015, table C403.2.3(5).

[1022] PG&E workpaper PGECOHVC142 and SCE workpaper SCE13HC036.1.

[1023] NPV analysis of PG&E workpaper PGECOHVC142 and SCE workpaper SCE13HC036.1. with assumptions of 2.2% inflation and 5% discount rate.

Measure Life

The measure life is assumed to be 15 years.[1024]

Operation and Maintenance Impacts

n/a

[1024] 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.

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

$$\Delta MMBTU = (SteamTrapDischargeRate * HOURS * h_{fg}) / (\eta Boiler * 1{,}000{,}000)$$

SteamTrapDischargeRate = 24.24[1025] * $Dia^2 * P_a$ * 50%

P_a = psig + psia

Where:

SteamTrapDischargeRate = Hourly rate of steam loss per trap (lb/hr).

[1025] 24.24 = Steam loss constant per Napier's equation (lb/hr-psia-in2)

HOURS = Actual operating hours/year
= If actual operating hours are unknown, use the Steam Trap Default Table below.

h_{fg} = Latent heat of vaporization (Btu/lb). See Heat of Vaporization table below.

ηBoiler = Thermal efficiency of boiler. Assume 80.7%[1026] if unknown.

Dia = Internal diameter of steam trap orifice. Use default value from Steam Trap Default table below if unknown.

P_a = Absolute steam pressure (psi)

psig = Steam gage pressure (psi). Use default value from Steam Trap Default table below if unknown.

psia = Atmospheric pressure (psi). Use standard atmospheric value, 14.7, if unknown.

50% = Deemed value for percent of orifice open.

Heat of Vaporization[1027]

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

[1026] T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993

[1027] The Engineering Toolbox, Properties of Saturated Steam - Imperial Units, https://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html

275	812
300	805

Steam Trap Default Table

Steam System	Average Steam Trap Inlet Pressure (psig)[1028]	Dia (diameter of orifice, in.)	HOURS[1029]
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

Steam System	Cost per trap ($)[1030]
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

[1028] 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.

[1029] Navigant analysis of Nicor Gas data from GPY1 to GPY3, “TRM Version 4.0 Steam Trap Measure Review”, October 2015

[1030] CLEAResult "Steam Traps Revision #1" dated August 2011, adjusted for 8 years of inflation at 2.2%.

Industrial High Pressure ≥175 <250 psig	$440
Industrial High Pressure ≥250 psig	$497

Measure Life

6 years[1031]

Operation and Maintenance Impacts

n/a

[1031] CA DEER – 2014 Updated EUL Records

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

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (\text{Savings }\%) * (HOURS_{heat} * CAP * 1/Eff) / 1{,}000{,}000$$

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).
= Actual.

Eff = *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 below[1032].

Savings Percentage

Boiler Reset	5.0%[1033]
Boiler Cut-Out	2.2%[1034]
Boiler Reset & Cut-Out	7.1%

Annual Water Savings Algorithm

[1032] Baseline efficiencies based on the Energy Independence and Security Act of 2007 and the International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[1033] 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.

[1034] 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%.

n/a

Incremental Cost

The cost of this measure is $812.[1035]

Measure Life

15 years[1036]

Operation and Maintenance Impacts

n/a

Reference Tables

Baseline Equipment Efficiency[1037]

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency	Minimum Efficiency after 3/2/2020
Boilers, Gas-fired	<300,000 BTU/h	Hot water	80% AFUE	80% AFUE
		Steam	75% AFUE	75% AFUE
	>=300,000 BTU/h and <=2,500,000 BTU/h	Hot water	80% E_t	80% E_t
		Steam – all, except natural draft	79.0% E_t	79.0% E_t
		Steam – natural draft	77.0% E_t	79% E_t
	>2,500,000 BTU/h	Hot water	82.0% E_c	82.0% E_c
		Steam – all, except natural draft	79.0% E_t	79.0% E_t
		Steam – natural draft	77.0% E_t	79% E_t

[1035] Nexant. Questar DSM Market Characterization Report. August 9, 2006, adjusted for 2.2% inflation for 13 years

[1036] New York State TRM v4.0, April 2016

[1037] Baseline efficiencies based on current federal standards (http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf) and standards for each state, ASHRAE 90.1 and IECC 2015.

Commercial Gas Furnace ≥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, ≥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.[1038]

Definition of Baseline Condition

The baseline condition is a gas furnace with a Thermal Efficiency (TE) of 80%[1039].

Definition of Efficient Condition

The efficient condition is a gas furnace with a TE of ≥90%.

Annual Electric Energy Savings Algorithm

NA

Summer Coincident Peak kW Savings Algorithm

NA

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (CAP * HOURS * (1/TE_{Base} - 1/TE_{Eff}) / 1,000,000)$$

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*

[1038] CFR Title 10 → Chapter II → Subchapter D → §431.71
[1039] CFR Title 10 → Chapter II → Subchapter D → §431.77

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
ΔMMBTU = 400,000 * 1,131 * (1/.80 – 1/.90) / 1,000,000
= 62.8 MMBtu

Annual Water Savings Algorithm

n/a

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 years[1040].

Operation and Maintenance Impacts

n/a

[1040] EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018 (prepared by Navigant Consulting, Inc.)

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

$$\Delta MMBTU = (1 - LRF) * CAP * HOURS_{heat} / 1{,}000{,}000$$

$$LRF = HDD45 / (55°F - T_{design}) / (HDD55 / (65°F - T_{design}))$$[1041]

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

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[1041] Minnesota TRM Version 2.2, May 2018. Page 383-386, "C/I HVAC - Infrared Heater".

$HDD55$ = 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.[1042]

Measure Life

12 years[1043]

Operation and Maintenance Impacts

n/a

Reference Tables

HDD, T_{design} and LRF values for selected cities[1044]

	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%

[1042] 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%.

[1043] Ibid.

[1044] Values based on TMY3 data. T_design placed at 99% percent lowest temperature.

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

The efficient condition is a high-efficiency packaged commercial freezer meeting ENERGY STAR Version 4.0 requirements[1045].

Annual Energy Savings Algorithm

Time of Sale or New Construction:

$$\Delta kWh = (kWh_{BASEdailymax} - kWh_{EEdailymax}) * 365.$$

Early Replacement:

ΔkWh for remaining life of existing unit:

$$= (kWh_{EXISTdailymax} – kWh_{EEdailymax}) * 365$$

[1045] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

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

$$= (kWh_{BASEdailymax} - kWh_{EEdailymax}) * 365$$

Where:

$kWh_{BASEdailymax}$ [1046] = *See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below.*

$kWh_{EEdailymax}$ [1047] = *See "Time of Sale Energy Star Equipment Efficiency" table in the "Reference Tables" section below.*

$kWh_{EXISTdailymax}$ = *See "Existing Equipment Efficiency" table in the "Reference Tables" section below*

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta kW = (\Delta kWh/HOURS) \times CF.$$

Early Replacement:

ΔkW for remaining life of existing unit:

$$= (\Delta kWh/HOURS) \times CF.$$

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

$$= (\Delta kWh/HOURS) \times CF.$$

Where:

HOURS = Full load hours.
= 5858. [1048]
CF = Summer Peak Coincidence Factor for measure.
= 0.77. [1049]

[1046] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[1047] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

[1048] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [1050]

The incremental cost for time of sale measure is assumed to be $0.[1051] 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.[1052]

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency

Product Class	**Freezer Energy** ($kWh_{BASEdailymax}$)
Vertical Closed	
Solid	*VCS.SC.L*
All volumes	0.22V+1.38
Transparent	*VCT.SC.L*
All volumes	0.29V+2.95
Horizontal Closed	
Solid	*HCS.SC.L*
All volumes	*0.06V+1.12*

[1049] 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.

[1050] Unit Energy Savings (UES) Measures and Supporting Documentation, ComFreezer_v3_0.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum

[1051] Energy Star Calculator accessed April 25, 2017, which cites Energy Star research, 2014.

[1052] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

Transparent	*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 ($kWh_{EEdailymax}$)**
Vertical Closed	
Solid	*VCS.SC.L*
$0 < V < 15$	0.21V+0.9
$15 \leq V < 30$	0.12V+2.248
$30 \leq V < 50$	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**[1053] ($kWh_{EXISTdailymax}$)	**Freezer Energy when existing unit was manufactured after 03/27/2017** ($kWh_{EXISTdailymax}$)
Vertical Closed		
Solid	*VCS.SC.L*	*VCS.SC.L*
All volumes	0.40V+1.38	0.22V+1.38

[1053] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2010).

Transparent	*VCT.SC.L*	*VCT.SC.L*
All volumes	0.75V+4.10	0.29V+2.95
Horizontal Closed		
Solid	*HCS.SC.L*	*HCS.SC.L*
All volumes	0.40V+1.38	*0.06V+1.12*
Transparent	*HCT.SC.L*	*HCT.SC.L*
All volumes	0.75V+4.10	0.08V+1.23

Where V = Unit volume in cubic feet

Early Replacement Remaining Useful Life and Incremental Cost[1054]

Age of Existing Unit Being Replaced	**Remaining Useful Life (RUL)**[1055]	**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
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

[1054] 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%.

[1055] Navigant analysis based on Weibull curve for refrigeration remaining useful life https://aceee.org/files/proceedings/2010/data/papers/1977.pdf

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

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.[1056]

Annual Energy Savings Algorithm

Time of Sale or New Construction:

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) * 365.$$

Early Replacement:

ΔkWh for remaining life of existing unit:

$$= (kWh_{EXISTdailymax} – kWh_{EEdailymax}) * 365$$

[1056] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

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

$= (kWh_{BASEdailymax} - kWh_{EEdailymax}) * 365$

Where:

$kWh_{BASEdailymax}$ [1057] = *See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below.*

$kWh_{EEdailymax}$ [1058] = *See "Time of Sale Energy Star Equipment Efficiency" table in the "Reference Tables" section below.*

$kWh_{EXISTdailymax}$ = *See "Existing Equipment Efficiency" table in the "Reference Tables" section below*

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

ΔkW

= (ΔkWh/HOURS) * CF.

Early Replacement:

ΔkW for remaining life of existing unit:

= (ΔkWh/HOURS) * CF.

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

= (ΔkWh/HOURS) * CF.

Where:

HOURS = *Full load hours.*

= *5858.* [1059]

CF = *Summer Peak Coincidence Factor for measure.*

[1057] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[1058] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

[1059] 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. [1060]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [1061]

The incremental cost for this time of sale measure is assumed to be \$0.**[1062]** 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.[1063]

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency

Product Volume (in cubic feet)	**Refrigerator (*kWhBASEdailymax)***
Vertical Closed	
Solid	*VCS.SC.M**
All volumes	0.05V+1.36
Transparent	*VCT.SC.M*
All volumes	0.1V+0.86
Horizontal Closed	
Solid	*HCS.SC.M*

[1060] 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.

[1061] Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigerator_v3.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum.

[1062] Energy Star Calculator accessed April 25, 2017, which cites Energy Star research, 2014.

[1063] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

All volumes	*0.05V+0.91*
Transparent	*HCT.SC.M*
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	
Solid	*VCS.SC.M**
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
Transparent	*VCT.SC.M*
0 < V < 15	0.095V+0.445
15 ≤ V < 30	0.05V+1.12
30 ≤ V < 50	0.076V+0.34
50 ≤ V	0.105V-1.111
Horizontal Closed	
Solid or Transparent	*HCT.SC.M, HCS.SC.M*
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**[1064] ($kWh_{EXISTdailymax}$)	**Refrigerator Energy when existing unit was manufactured after 03/27/2017** ($kWh_{EXISTdailymax}$)
Vertical Closed		

[1064] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2010)..

Solid	*VCS.SC.M*	*VCS.SC.M*
All volumes	0.10V+2.04	0.05V+1.36
Transparent	*VCT.SC.M*	*VCT.SC.M*
All volumes	0.12V + 3.34	0.1V+0.86
Horizontal Closed		
Solid	*HCS.SC.M*	*HCS.SC.M*
All volumes	0.10V+2.04	*0.05V+0.91*
Transparent	*HCT.SC.M*	*HCT.SC.M*
All volumes	0.12V + 3.34	0.06V+0.37

Where V = Unit volume in cubic feet

Early Replacement Remaining Useful Life and Incremental Cost[1065]

Age of Existing Unit Being Replaced	Remaining Useful Life (RUL)[1066]	Incremental Cost of Measure $0 \le V < 25$	Incremental Cost of Measure $25 \le V$
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
14	3	$ 212	$ 461
15	3	$ 212	$ 461
16	3	$ 212	$ 461

[1065] 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%.

[1066] Navigant analysis based on Weibull curve for refrigeration remaining useful life https://aceee.org/files/proceedings/2010/data/papers/1977.pdf

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

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:

LOAD = average refrigeration load per linear foot of refrigerated case without night covers deployed.
= 1,500 BTU/h[1067] *per linear foot.*
FEET = linear (horzontal) 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.

[1067] 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>

= assume 2.2[1068]*, if actual value is unknown.*

ESF = Energy Savings Factor; reflects the percent reduction in refrigeration load due to the deployment of night covers
= 9%.[1069]

8,760 = assumed annual operating hours of the refrigerated case.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0$$ [1070]

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.[1071]

Measure Life

The expected measure life is assumed to be 5 years.[1072]

Operation and Maintenance Impacts

n/a

[1068] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.

[1069] 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.

[1070] Assumed that the continuous covers are deployed at night; therefore no demand savings occur during the peak period.

[1071] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008 <http://deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip>

[1072] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

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

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.*[1073]

$\%ON_{NONE}$ = *Effective run time of uncontrolled ASDH.*

= *assume 90.7%.*[1074]

$\%ON_{CONTROL}$ = *Effective run time of ASDH with controls.*

= *assume 58.9% for ON/OFF controls and 42.8% for micropulse controls.*[1075]

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.*

= *assume 1.25 for cooler and 1.50 for freezer applications.*[1076]

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 heatersthat 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 unkown, use deemed estimates in the table below.*[1077]

Control Type	$CF_{refrigerator}$	$CF_{freezer}$
On/Off Controls	0.25	0.21

[1073] Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

[1074] Ibid.

[1075] Ibid.

[1076] 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.

[1077] Ibid.

Micropulse Controls	0.36	0.30

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

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 door[1078]. Values include labor costs.

Measure Life

The expected measure life is assumed to be 12 years.[1079]

Operation and Maintenance Impacts

n/a

[1078] Navigant. 2015. *Incremental Cost Study Phase Four, Final Report*. Burlington, MA.

[1079] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

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

$$\Delta kWh = kW_{hp} * HP * \%\Delta_P * \%ON_{UC} * HOURS * WHFe.$$

Where:

kW_{hp} = ECM connected load kW per horsepower.
= If actual kW_{hp} is unknown, assume 0.758 kW/hp.[1080]
HP = Horsepower of ECM.
= Actual horsepower of ECM.

[1080] Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

$\%\Delta_P$ = *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%.*[1081]

$\%ON_{UC}$ = *Effective run time of uncontrolled motors.*
= *If actual $\%ON_{UC}$ is unknown, assume 97.8%.* [1082]

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.* [1083]

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.* [1084]

CF = *Summer Peak Coincidence Factor.*
= *If site specific CFs are unknown, use 1.53.*[1085]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

[1081] Ibid.

[1082] Ibid.

[1083] Ibid.

[1084] Ibid.

[1085] 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.

Incremental Cost

The incremental capital cost is $61. Values include labor costs.[1086]

Measure Life

The expected measure life is assumed to be 15 years.[1087]

Operation and Maintenance Impacts

n/a

[1086] 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.

[1087] Energy & Resource Solutions (ERS). 2005. Measure Life Study: prepared for The Massachusetts Joint Utilities

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

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.[1088]

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 unkown, assume 97.8%. [1089]

$\%ON_{CONTROL}$ = Effective run time of motor with controls.

= Assume 63.6% for ON/OFF style controls and 69.2% for multi-speed style controls. [1090]

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.[1091]

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.[1092]

CF = Summer Peak Coincidence Factor.

= If site specific CFs are unkown, use 0.26.[1093]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

[1088] Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

[1089] Ibid.

[1090] Ibid.

[1091] Ibid.

[1092] Ibid.

[1093] 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.

n/a

Incremental Cost

The incremental capital cost is $532 for multispeed controls[1094]. Value includes labor costs.

The actual measure installation cost for ON/OFF controls should be used (including materials and labor)[1095].

Measure Life

The expected measure life is assumed to be 10 years.[1096]

Operation and Maintenance Impacts

n/a

[1094] Navigant. 2015. *Incremental Cost Study Phase Four, Final Report*. Burlington, MA.

[1095] 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.

[1096] Energy & Resource Solutions (ERS). 2005. Measure Life Study: prepared for The Massachusetts Joint Utilities.

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.[1097]

Definition of Efficient Condition

The efficient condition is a new complete gasket.

Annual Energy Savings

$$\Delta kWh = SPF_e * L$$

Where:

SPF_e = *Annual Energy Savings per Foot of gasket, given in the table below.*

Refrigeration Type	Energy Savings (kWh /foot)[1098]
Low Temp (Freezer) Reach-in	27.3
Med Temp (Cooler) Reach-in	18.2
Low Temp (Freezer)	33.1

[1097] BPA sponsored Emerson study. “Study of Typical Gasket Deterioration”, Feb 27, 2008, Emerson Design Services Network. https://slideplayer.com/slide/4525301/

[1098] BPA sponsored Emerson study. “Study of Typical Gasket Deterioration”, Feb 27, 2008, Emerson Design Services Network. https://slideplayer.com/slide/4525301/.

Walk-in	
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*

Refrigeration Type	Peak Demand Reduction (kW /foot)[1099]
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.[1100] This is for the full length replaced, not the length damaged.

[1099] 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.

Measure Life

The measure life is assumed to be 4 years.[1101]

Operation and Maintenance Impacts

n/a

[1100] BPA sponsored Emerson study. “Study of Typical Gasket Deterioration”, Feb 27, 2008, Emerson Design Services Network. https://slideplayer.com/slide/4525301/

[1101] Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, California Public Utility Commission, February 2010.

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

$$\Delta kWh = (kBTU\_req / 3.413) * ((1/EFbase) - (1/EFee))$$

Where:

kBTU_req (Office) = *Required annual heating output of office (kBTU)*
= *6,059.*[1102]
kBTU_req (School) = *Required annual heating output of school (kBTU)*
= *22,191.*[1103]

[1102] Assumes an office with 25 employees; According to 2003 ASHRAE Handbook: HVAC Applications, Office typically uses 1.0 gal/person per day.
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.

[1103] 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.

3.413 = *Conversion factor from kBTU to kWh.*
EFee = *Energy Factor of Heat Pump domestic water heater.*
= *2.0.*[1104]
EFbase = *Energy Factor of baseline domestic water heater.*
= *0.904.*[1105]

ΔkWh Office = (6,059 / 3.413) * ((1/0.904) – (1/2.0)).
= 1076.2 kWh.

ΔkWh School = (22,191 / 3.413) * ((1/0.904) – (1/2.0)).
= 3941.4 kWh.

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

ΔkW = ΔkWh / Hours * CF

Where:

Hours (Office) = *Run hours in office.*
= *5885.*[1106]

[1104] 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

[1105] Ibid.

[1106] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

Hours (School) = *Run hours in school.*
= *2218.* [1107]
CF (Office) = *Summer Peak Coincidence Factor for office measure.*
= *0.630.* [1108]
CF (School) = *Summer Peak Coincidence Factor for school measure.*
= *0.580.* [1109]

ΔkW Office = (1076.2 / 5885) * 0.630.
= 0.12 kW.
ΔkW School = (3941.4 / 3.413) * 0.580.
= 1.03 kW.

If annual operating hours and CF estimates are unknown, use deemed HOURS and CF estimates above. Otherwise, use site specific values.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

[1107] Ibid.
[1108] Ibid.
[1109] Ibid.

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided below.[1110]

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.[1111]

Operation and Maintenance Impacts

n/a

[1110] 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.

[1111] Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005.

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

$$\Delta kWh = \Delta Water \text{ x } HOT\% \text{ x } 8.33 \text{ x } (\Delta T) \text{ x } (1/EFF) / 3413.$$

Where:

ΔWater = *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%.*[1112]
8.33 = *The energy content of heated water (BTU/gallon/°F).*

[1112] 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.

ΔT = Temperature rise through water heater (°F).
= 70.[1113]
EFF = Water heater thermal efficiency.
= 0.97.[1114]
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:
EFF = Water heater thermal efficiency.
= 0.75[1115]*.*
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:[1116]

[1113] Engineering judgment; assumes typical supply water temperature of 70°F and a hot water storage tank temperature of 140°F.
[1114] Federal Standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/51
[1115] IECC 2006. Performance requirement for gas water heaters.
[1116] Hours estimates based on *PG&E savings estimates, algorithms, sources* (2005). Food Service Pre-Rinse Spray Valves

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 5 years.[1117]

Operation and Maintenance Impacts

n/a

[1117] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

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 standards[1118], 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 specifications[1119] effective October 1, 2018. See Efficiency Criteria Table below.

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[1120]	Gas-fired storage water heaters meeting ENERGY STAR criteria	≤0.84 * [IR/800 + 110 * (Vs^.5)]	≥94%

[1118] Federal minimum standards for standby loss and TE CFR Title 10 → Chapter II → Subchapter D → Part 431 Subpart G

[1119] ENERGY STAR Commercial Water Heater Key Product Criteria

[1120] ENERGY STAR Commercial Water Heater eligibility criteria v2.0

Annual Fossil Fuel Savings Algorithm

Annual MMBTU savings is the sum of standby loss savings and thermal efficiency savings.

ΔMMBtu =
((IR/800 + 110 * (Vs^.5)) – (.84 * IR/800 + 110 * (Vs^.5))* 8,760 / 1,000,000)
+ (MMBTU/yr$_{act}$ x (1-(TE$_{base}$ / TE$_{eff}$)))

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
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)

Btu/hr = IR / 800 + 110 * (Vs^.5)
= 150,000/800 + 110 * (100^.5)
= 1,287.5 Maximum allowable

Standby Loss of efficient unit (Max)

Btu/hr = .84 * IR / 800 + 110 * (Vs^.5)
= .84 * 150,000/800 + 110 * (100^.5)
= 1,081.5 Maximum allowable
= 1,000 as rated (rated takes precedence)

Annual Standby Loss Savings

ΔMMBtu = (standby loss of efficient unit – standby loss of baseline unit) * 8,760 / 1,000,000
= (1,287.5 – 1,000) * 8,760 / 1,000,000
= 2.5 MMBtu/yr savings

Annual Thermal Efficiency Savings

ΔMMBtu = $MMBtu/yr_{act}$ x $(1-(TE_{base} / TE_{eff}))$
= 200 * (1-(.80 / .96))
= 33.3

Total Annual Savings

Total Annual MMBtu Savings = Annual Standby Loss Savings + Annual Thermal Efficiency Savings
= 2.5 + 33.3
= 35.8 MMBtu

Incremental Cost

$1,510[1121]

Measure Life

The measure life is assumed to be 10 years[1122]

[1121] NEEP Water Heating, Boiler and Furnace Cost Study September 2018, adjusted to 2019 dollars, 50 gallon, 100 MBH

[1122] EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018

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 standards[1123] for consumer products (due to ≤75kBtu input rating) referencing the Uniform Energy Factor (UEF) energy performance criteria. This specification became effective December 29, 2016[1124].

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 STAR water heater requirements Version 3.2[1125], referencing Energy Factor (EF) or Uniform Energy Factor[1126] (UEF) energy performance criteria, effective April 16, 2015.

Commercial Gas Storage Water Heater ≤75kBtu Efficiency Criteria						
	ENERGY STAR allows for qualification with EF or UEF (see ES v3.2 Specs)		**Min. Uniform Energy Factor (UEF)** based on hot water draw pattern			
Condition	**Storage Volume (Vs)**	**Min. Energy Factor (EF)**	*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)

[1123] Title 10 →Chapter II →Subchapter D →Part 430 →Subpart C →§430.32

[1124] Docket No. EERE-2015-BT-TP-0007

[1125] ENERGY STAR® v3.2 Program Requirements for Residential Water Heaters

[1126] Title 10 →Chapter II →Subchapter D →Part 430 Appendix E

	>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 rating[1127] 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.[1128]

Draw Pattern based on First Hour Rating	
First Hour Rating	**Draw Pattern**
<18 gallons	Very Small
=18 and <51 gallons	Low
=51 and <75 gallons	Medium
≥75 gallons	High

Annual Fossil Fuel Savings Algorithm, UEF Method

$\Delta MMBTU = MMBtu/yr_{act} * UEF_{base} * (1/ UEF_{base} – 1/UEF_{eff})$

Annual Fossil Fuel Savings Algorithm, EF Method

$\Delta MMBTU = MMBtu/yr_{act} * EF_{base} * (1 / EF_{base} – 1 / EF_{eff})$

Where:

$MMBtu/yr_{act}$ = 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

Vs = rated storage volume (gallons)

[1127] CFR part 430 App E 5.4.1

[1128] Title 10 → Chapter II → Subchapter D → Part 430 → E → Table 5.4.1

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.

ΔMMBTU = 50 MMBtu/yr_{act} * .62 * (1/.62 – 1/.68)
= 31 * .14
= 4.41 MMBtu/yr savings

Incremental Cost
$377[1129]

Measure Life
The measure life is assumed to be 13 years[1130]

[1129] NEEP Water Heating, Boiler and Furnace Cost Study September 2018, adjusted to 2019 dollars, 50 gallon, 40 MBH

[1130] EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018 (average)

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:[1131]

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.

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.

[1131] U.S. EPA. 2015. ENERGY STAR® Program Requirements Product Specification for Clothes Washers Eligibility Criteria Version 7.1

Annual Energy Savings Algorithm

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{DHW} + \Delta kWh_{DRYER}$$

$$\Delta kWh_{CW} = (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE}) * \%CW$$

$$\Delta kWh_{DHW} = (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE}) * \%DHW * DHW_{ELEC}$$

$$\Delta kWh_{DRYER} = [(kWh_{TOTAL,BASE} - kWh_{TOTAL,EE}) - (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE})] * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE\_MOD} * DRYER_{ELEC}$$

$$kWh_{UNIT,i} = kWh_{UNIT\_RATED,i} * Ncycles / Ncycles\_ref$$

$$kWh_{TOTAL,i} = Capacity / MEF_i * Ncycles$$

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.*[1132]

$kWh_{UNIT\_RATED,\ EE}$ = *Efficient rated unit electricity consumption.*
= *If actual value unknown, assume 97 kWh/yr.*[1133]

%CW = *Percentage of unit energy consumption used for clothes washer operation.*
= *If unknown, assume 20%.*[1134]

[1132] 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

[1133] Ibid.

[1134] Ibid.

%DHW = Percentage of unit energy consumption used for water heating.
= If unknown, assume 80%.[1135]
DHW_{ELEC} *= 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.[1136]

Efficiency Level	Modified Energy Factor (MEF)	
	Front Loading	Top Loading
Federal Standard	Before January 1, 2018	
	>= 2.00	>= 1.60
	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.[1137]
Ncycles_ref = Reference number of cycles per year.
= 392.[1138]
$\%LOADS_{DRYED}$ *= Percentage of washer loads dried in machine.*
= If actual value unknown, assume 100%.
$DRYER_{USAGE}$ *= Dryer usage factor.*
= 0.84.[1139]

[1135] Ibid.

[1136] 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.

[1137] 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

[1138] Ibid.

[1139] Ibid.

$DRYER_{USAGE\_MOD}$ = *Dryer usage in buildings with dryer and washer*
= *0.95.*[1140]
$DRYER_{ELEC}$ = *1 if electric dryer; 0 if gas dryer.*

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:

Hours = *Assumed Run hours of Clothes Washer.*
= *265.*[1141]
CF = *Summer Peak Coincidence Factor for measure*
= *0.029.*[1142]

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*

[1140] Ibid.

[1141] 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 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.

[1142] Ibid.

DHW_{EFF} = *Gas water heater efficiency.*
= *If actual unknown, assume 75%.*
MMBTU _convert = *Convertion 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.*[1143]
$DRYER_{GAS}$ = *1 if gas dryer; 0 if electric dryer.*

Annual Water Savings Algorithm

$$\Delta\text{Water (CCF)} = \text{Capacity} * (WF_{BASE} - WF_{EE}) * \text{Ncycles} / 748$$

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	Before January 1, 2018	
	<= 5.5	<= 8.5
	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.

$$\Delta kWh_{water}{}^{1144} = 2.07 \text{ kWh/CCF} * \Delta\text{Water (CCF)}$$

[1143] 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

[1144] 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.

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is $200.[1145]

Measure Life

The measure life is assumed to be 7 years. [1146]

Operation and Maintenance Impacts

n/a

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.

[1145] 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.

[1146] Ibid

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. The efficient device effectively eliminates standby power consumption for all controlled devices[1147] when the master load is not in use.

Annual Energy Savings Algorithm

$\Delta kWh = 26.9\ kWh$[1148]

[1147] 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.

[1148] 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

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

The incremental cost for this time of sale measure is assumed to be $18[1149].

Measure Life

The measure life is assumed to be 4 years.[1150]

Operation and Maintenance Impacts

n/a

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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.

[1149] 2016 Illinois Technical Resource Manual

[1150] David Rogers, Power Smart Engineering, "Smart Strip Electrical Savings and Usability," October 2008.

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.[1151] 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

The efficient equipment is assumed to be an ENERGY STAR qualified electric or gas fryer.[1152]

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

[1151] 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.

[1152] US EPA. December 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Version 3.0

Where:[1153]

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.*
= *if average daily operating hours are unknown, assume default of 16 hours/day for standard fryers and 12 hours/day for large vat fryers.*

E_{FOOD} = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.167.*

LB = *Pounds of food cooked per day (lb/day).*
= *if average pounds of food cooked per day is unknown, assume default of 150 lbs/day.*

DAYS = *annual days of operation.*
= *if annual days of operation are unknown, assume default of 365 days.*

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.*

[1153] 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>

Electric Fryer Performance Metrics: Baseline and Efficient Values

Parameter	Standard Size Baseline Model	Standard Size Energy Efficient Model	Large Vat Baseline Model	Large Vat 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 [1154]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$MMBTU\_Idle_i = IDLE_i \times (HOURS_{DAY} – LB/PC_i)$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} – LB/PC_i)] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

Where:[1155]

$MMBTU\_Cooking_i$ = 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.

[1154] 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.

[1155] 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>

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

	Standard Size		Large Vat	
Parameter	**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

n/a

Incremental Cost[1156]

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 years[1157]

Operation and Maintenance Impacts

n/a

[1156] 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>

[1157] 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>

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.[1158]

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = [(1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD}/EFF_i] \times TIME_{idle}$$

$$TIME_{idle} = (HOURS_{DAY} – LB/(PC_i \times PANS))$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + ((1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD}/EFF_i) \times (HOURS_{DAY} – LB/(PC_i \times PANS))] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:[1159]

[1158] US EPA. August 2003. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers Eligibility Criteria Version 1.2

[1159] 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_equipm

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).*
= *if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.*
E_{FOOD} = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.0308.*
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.*
PCT_{steam} = *percent of time in constant steam mode (%).*
= *if percent of time in constant steam mode is unknown, assume default of 40%.*
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 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 16.7.*
PANS = *number of pans per unit.*
= *actual installed number of pans per unit.*
$HOURS_{DAY}$ = *average daily operating hours.*
= *if average daily operating hours are unknown, assume default of 12 hours/day.*

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ent_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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 [1160]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$

$$MMBTU\_Idle_i = [(1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD} /EFF_i] \times TIME_{idle}$$

$$TIME_{idle} = (HOURS_{DAY} – LB/(PC_i \times PANS))$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + ((1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD} /EFF_i) \times (HOURS_{DAY} – LB/(PC_i \times PANS))] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

Where: [1161]

[1160] 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.

[1161] 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>

$MMBTU_{base}$ = 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

		Baseline Model		Energy Efficient Model
Parameter	**No. of Pans**	**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

ΔWater = $(GPH_{base} – GPH_{eff})$ x $HOURS_{DAY}$ x DAYS.

Where:[1162]

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.

[1162] 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>

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.*

		Baseline Model	**Energy Efficient Model**		
Parameter	**No. of Pans**	**All**	**Steam Generator**	**Boiler Based**	**Boilerless**
GPH	All	40	15	10	3

Incremental Cost[1163]

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 years[1164]

Operation and Maintenance Impacts

n/a

[1163] 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>

[1164] Ibid.

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.[1165]

Annual Energy Savings Algorithm

$$\Delta kWh = (IDLE_{base} - IDLE_{eff}) / 1000 \times HOURS_{DAY} \times DAYS$$

Where:[1166]

$IDLE_{base}$ = *the idle energy rate of the baseline equipment (W). See table below for calculation of default values.*

$IDLE_{eff}$ = *the idle energy rate of the efficient equipment (W). If actual efficient values are unknown, assume default values from table below.*

1,000 = *conversion of W to kW.*

$HOURS_{DAY}$ = *average daily operating hours.*

[1165] US EPA. April 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0.

[1166] 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>

= if average daily operating hours are unknown, assume default of 15 hours/day.

DAYS = annual days of operation.

= if annual days of operation are unknown, assume default of 365 days.

Summer Coincident Peak kW Savings Algorithm [1167]

$$\Delta kW = (IDLE_{base} - IDLE_{eff}) / 1000$$

Hot Food Holding Cabinet Performance Metrics: Baseline and Efficient Values

VOLUME (Cubic Feet)	Product Idle Energy Consumption Rate (Watts)	
	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 (ft^3).

= actual volume of installed unit

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [1168]

The incremental cost for a for this time of sale measure ENERGY STAR hot food holding cabinets is assumed to be $0.

Measure Life

[1167] 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.

[1168] 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>

12 years[1169]

Operation and Maintenance Impacts

n/a

[1169] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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.[1170]

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times SIZE \times [HOURS_{DAY} – LB/(PC_i \times SIZE)]$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times SIZE \times (HOURS_{DAY} – LB/(PC_i \times SIZE))] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:[1171]

[1170] US EPA. January 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles Eligibility Criteria Version 1.2.

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.*

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/ft^2).

= *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* (ft^2).

$HOURS_{DAY}$ = *average daily operating hours.*

= *if average daily operating hours are unknown, assume default of 12 hours/day.*

PC = *Production capacity* ($lb/hr/ft^2$).

= *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

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[1171] 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>

Parameter	Baseline Model	Efficient Model
IDLE (kW/ft^2)	0.40	0.32
EFF	65%	70%
PC	5.83	6.67

Summary Coincident Peak kW Savings Algorithm [1172]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

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:[1173]

$MMBTU\_Cooking_i$ = 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.
= 0.000475.

[1172] 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.

[1173] 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>

IDLE = *Idle energy rate (MMBTU/h/ft^2).*
= *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 Cost[1174]

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 years[1175]

Operation and Maintenance Impacts

n/a

[1174] 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>

[1175] Ibid.

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.[1176]

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

[1176] US EPA. October 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2

Where:[1177]

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.*

= *if average daily operating hours are unknown, use default values from Oven Operation by Building Type below*

$DAYS$ = *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[1178]

[1177] 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>

Facility Type	hours/day	days/year
Community College	11	283
Fast Food Restaurant	14	363
Full Service Restaurant	12	321
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 Values[1179]

	Half Size		Full Size	
Parameter	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 Algorithm [1180]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$

$$MMBTU\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

[1178] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

[1179] Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php.

[1180] 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.

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} – LB/PC_i)] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

Where:[1181]

$MMBTU\_Cooking_i$ = 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.

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 Cost

The incremental cost for this time of sale measure is assumed to be $0.[1182]

[1181] 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>

[1182] 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>

Measure Life

12 years[1183]

Operation and Maintenance Impacts

n/a

[1183] 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>

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.[1184]

Annual Energy Savings Algorithm

$$kWh_{i,j} = (kWh\_Cooking_{i,j} + kWh\_Idle_{i,j}) \times DAYS$$

$$kWh\_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$$
$$kWh\_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} – LB/PC_{i,j}) \times PCT_j$$

$$kWh_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} – LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$kWh_{base} = kWh_{base,conv} + kWh_{base,steam}$$
$$kWh_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

[1184] US EPA. October 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2

Where:[1185]

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.*
= *if average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in "Commercial Convection Ovens"*

$DAYS$ = *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".*

$E_{FOOD,conv}$ = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during convention mode cooking, per pound of food.*
= *0.0732.*

$E_{FOOD,steam}$ = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during steam mode cooking, per pound of food.*
= *0.0308.*

LB = *Pounds of food cooked per day (lb/day).*
= *if average pounds of food cooked per day is unknown, assume default of 200 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).*

[1185] 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>

= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

PCT_j = *percent of food cooked in cooking mode j. Note: PCT_{conv} + PCT_{steam} must equal 100%.*

= 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 + 0.4989	0.133 x PANS + 0.64
	>= 15	2.280	8.710		
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 [1186]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_{i)}] \times DAYS$$

$$MMBTU\_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$$

$$MMBTU\_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j}) \times PCT_j$$

$$MMBTU_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$MMBTU_{base} = kWh_{base,conv} + kWh_{base,steam}$$

$$MMBTU_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

[1186] 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.

$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$

Where:[1187]

$MMBTU\_Cooking_i$ = *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.*
= *0.000105.*

LB = *Pounds of food cooked per day (lb/day).*
= *if average pounds of food cooked per day is unknown, assume default of 250 lbs/day.*

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 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 (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

[1187] 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>

Parameter	No. of Pans	Baseline Model		Energy Efficient Model	
		Convection Mode	Steam Mode	Convection Mode	Steam Mode
	>= 15 and < 30	176	211	210	277
	>= 30	392	579	394	640

Note: PANS = The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this time of sale measure commercial combination ovens is assumed to be $0.[1188]

Measure Life

12 years[1189]

Operation and Maintenance Impacts

n/a

[1188] 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>

[1189] Ibid.

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 requirements[1190].

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBTU} = \text{DAYS} * (\Delta \text{BTU}_{\text{preheat}} + \Delta \text{BTU}_{\text{idle}} + \Delta \text{BTU}_{\text{cooking}}) / 1{,}000{,}000$$

$$\Delta \text{BTU}_{\text{preheat}} = \text{N}_{\text{preheat}} * (\text{BTU}_{\text{preheat,baseline}} - \text{BTU}_{\text{preheat,ee}})$$

$$\Delta \text{BTU}_{\text{idle}} = (\text{BTU/h}_{\text{idle,baseline}} - * \text{BTU/h}_{\text{idle,ee}}) * (\text{HOURS}_{\text{day}} - \text{N}_{\text{preheat}} * \text{hrs}_{\text{preheat}} - (\text{LB} / \text{PC}))$$

$$\Delta \text{BTU}_{\text{cooking}} = \text{LB} * \text{E}_{\text{food}} * (1/\text{Eff}_{\text{baseline}} - 1/\text{Eff}_{\text{ee}})$$

Where:

[1190] ENERGY STAR Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2, ENERGY STAR, October 2015.

$DAYS$ = 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 1[1191] preheat per day.

$hrs_{preheat}$ = Preheat duration (hrs). Assume 0.33[1192] if unknown.

$BTU_{preheat,base}$ = Equipment preheat energy (BTU). Use default values in Default Assumptions for Rack Ovens below.

$BTU_{preheat,ee}$ = 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 235[1193] if unknown.

Eff_{base} = Equipment convection/steam mode cooking efficiency (%). Use 30%[1194] 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 Ovens[1195]

[1191] PG&E Work Paper PGECOFST109 Revision 5, Table 12, pg. 7, Download from http://deeresources.net/workpapers

[1192] Ibid.

[1193] Ibid.

[1194] Ibid.

Variable	Rack Oven, Gas, Double Rack	Rack Oven, Gas, Single Rack
LB	1,200	600
$BTU_{preheat,baseline}$	100,000	50,000
$BTU_{preheat,ee}$	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 Cost

The incremental cost for this time of sale measure is assumed to be $4,128[1196]

Measure Life

12 years[1197]

Operation and Maintenance Impacts

n/a

[1196] PG&E Work Paper PGECOFST109 Revision 5, At-a-Glance Summary, page ii – Download from http://deeresources.net/workpapers

[1197] Food Service Technology Center: Gas Rack Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-rack-ovens/#calc

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

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = DAYS * (\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}) / 1{,}000{,}000$$

$$\Delta BTU_{preheat} = N_{preheat} * (BTU_{preheat,baseline} – BTU_{preheat,ee})$$

ΔBTU_{idle} = $(BTU/h_{idle,baseline}$ - * $BTU/h_{idle,ee}$) * $(HOURS_{day} – N_{preheat}$ * $hrs_{preheat}$ – (LB / PC))

$\Delta BTU_{cooking}$ = LB * E_{food} * $(1/Eff_{baseline} – 1/Eff_{ee})$

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[1198] preheat per day.

$hrs_{preheat}$ = Preheat duration (hrs). Assume 0.25[1199] if unknown.

$BTU_{preheat,base}$ = Equipment preheat energy (BTU). Use 35,000[1200] by default.

$BTU_{preheat,ee}$ = Actual equipment preheat energy (BTU).

$BTU/h_{idle,base}$ = Equipment idle energy rate (BTU/h). Use 70,000[1201] by default.

$BTU/h_{idle,ee}$ = Actual equipment idle energy rate (BTU/hr).

LB = Pounds of food cooked per day (lb/day). Use 190[1202] if unknown.

$PC_{baseline}$ = Production capacity (lb/hr). Use 114[1203] 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[1204] if unknown.

[1198] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, Download from http://deeresources.net/workpapers

[1199] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6 - Download from http://deeresources.net/workpapers

[1200] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

[1201] Ibid.

[1202] 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

[1203] 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

[1204] 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

$Eff_{baseline}$ = Equipment convection/steam mode cooking efficiency (%). Use 20%[1205] if unknown.

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 $2,230[1206].

Measure Life

12 years[1207]

Operation and Maintenance Impacts

n/a

[1205] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

[1206] PG&E Work Paper PGECOFST117 Revision 5, At-a-Glance Summary, pg. ii - Download from http://deeresources.net/workpapers

[1207] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

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 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 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.

Annual Energy Savings Algorithm

$\Delta kWh = (ECR_{base} - ECR_{EE})/100 \times DAYS \times DUTY \times H$

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.*

= *0.40*[1208]

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)**[1209]	**ENERGY STAR Maximum Energy Consumption Rate (kWh/100 lb ice)**[1210]
Ice-Making Head	< 300	10-0.01233*H	9.20 - 0.01134*H
Ice-Making Head	≥ 300 and < 800	7.05-0.0025*H	6.49 - 0.0023*H
Ice-Making Head	≥ 800 and <	5.55-0.00063*H	5.11 - 0.00058*H

[1208] Duty cycle varies considerably from one installation to the next. TRM assumptions from Vermont, Wisconsin, and New York vary from 40 to 57%, whereas the ENERGY STAR Commercial Ice Machine Savings Calculator <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Ice_Machines.xls> assumes a value of 75%. A field study of eight ice machines in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007). Furthermore, a report prepared by ACEEE assumed a value of 40% (Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002). For conservatism, this characterization assumed a value of 40%.

[1209] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53

[1210] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

	1,500		
Ice-Making Head	≥ 1500 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

Continuous Type Commercial Ice Makers			
Equipment type	**Harvest rate (lb ice/24 hours)**	**Federal Baseline Maximum Energy Consumption Rate (kWh/100 lb ice)**[1211]	**ENERGY STAR Maximum Energy Consumption Rate (kWh/100 lb ice)**[1212]
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	<800	9.7-0.0058*H	7.76 – 0.00464*H

[1211] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53

[1212] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

compressor)			
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
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 [1213]

$$\Delta kW = (ECR_{base} - ECR_{EE})/2,400 \times H \times CF$$

Where:

CF = Summer Peak Coincident Factor for measure
= 0.772 [1214]

Annual Fossil Fuel Savings Algorithm

n/a

Water Savings Algorithm[1215]

[1213] 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.

[1214] 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.

[1215] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipm

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 Cost[1216]

The incremental cost for this time of sale measure ENERGY STAR commercial ice maker is assumed to be $0.

Measure Life

8 years[1217]

Operation and Maintenance Impacts

n/a

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ent_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[1216] 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>

[1217] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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.[1218]

Definition of Efficient Condition

The efficient condition is a high-efficiency commercial dishwasher meeting ENERGY STAR Version 2.0 requirements.[1219]

Annual Energy Savings Algorithm

$\Delta kWh = kWh_{Base} - kWh_{EFF}$

Where:

kWh_{BASE} = *Baseline kWh consumption per year*

[1218] 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.

[1219] ENERGY STAR Program Requirements for Commercial Dishwashers Version 2.0, ENERGY STAR, February 2013.

= *Values provided in tables below.*

kWh_{EFF} = *ENERGY STAR kWh consumption per year*

= *Values provided in tables below.*

Commercial Dishwasher Annual Energy Use (kWh)[1220]

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
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)[1221]

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

[1220] 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>

[1221] 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>

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

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW \quad = \Delta kWh \times CF / HOURS$$

Where:

HOURS = annual operating hours.
=5,634[1222]
CF = Summer Peak Coincident Factor for measure
= 0.9[1223]

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu \quad = MMBtu_{BASE} - MMBtu_{EFF}$$

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)[1224]				
Building hot water fuel type / Booster water heater fuel type	**Electric / Electric**		**Electric / Natural Gas**	
	Baseline	**ENERGY STAR**	**Baseline**	**ENERGY STAR**

[1222] 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.

[1223] PG&E Work Paper PGECOFST126 Revision 0, Table 10, pg. 18

[1224] 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>

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)[1225]				
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	29.2	20.1	29.2	20.1
Stationary Single Tank Door	132.2	74.3	132.2	74.3
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

[1225] 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>

Annual Water Savings Algorithm

$$\Delta\text{Water (CCF)} = \text{Water}_{BASE} - \text{Water}_{EFF}$$

Where

Water_{BASE} = Annual water consumption of baseline unit.
= Values provided in tables below.
Water_{EFF} = Annual water consumption of ENERGY STAR unit.
= Values provided in tables below.

	Annual Water Consumption (CCF)[1226]	
	Baseline	**ENERGY STAR**
Low Temperature		
Under Counter	54.3	37.3
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. [1227]

[1226] 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>

[1227] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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
	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.[1228]

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

[1228] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

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 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:

$$\Delta kWH = \Delta kWh_{fan} + \Delta kWh_{cooling}$$

$$\Delta kWh_{fan} = \left(\frac{CFM}{1400\text{[1229]}}\right) * Hours * Days * Weeks * \sum_{0\%}^{100\%}(\%FF * PLR)$$

[1229] Estimation of CFM delivered per kW consumed from both exhaust and make-up air fan motor. Derived from proprietary Navigant DCKW tool.

$$\Delta kWh_{cooling} = SF_{Cool} * \%MUA_{Cool} * \Delta kWh_{fan}$$

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.*
= *For Flow Fractions abvoe 50%, PLR = 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.[1230]

$\%MUA_{Cool}$ = 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

[1230] 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.

$$\Delta kW = \Delta kWh/(Hours * Days * Weeks) * CF$$

Where:

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})[1231]

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
80%	0.0104	0.0122
90%	0.0117	0.0126
100%	0.0130	0.0130

Annual Water Savings Algorithm

[1231] 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.

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.[1232]

Operation and Maintenance Impacts

n/a

[1232] DEER 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.

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

ΔkWh = 0.9[1233] * HP * HOURS * ($COMPF_{base}$ – $COMPF_{ee}$)

Where:

HP = *Compressor motor nominal HP*
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, 0.705*[1234]

[1233] Compressor motor nominal HP to full load kW conversion factor.

[1234] Efficiency Vermont Technical Reference User Manual (TRM) No. 2015-87C..

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

Incremental Cost

Incremental cost = ($127 * HP) + $1,446[1235]

Measure Life

The measure life is assumed to be 13 years[1236].

Operation and Maintenance Impacts

n/a

Reference Tables

[1235] Efficiency Vermont Technical Reference User Manual (TRM) No. 2015-87C.

[1236] 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.

Compressor Total Hours of Operation and Coincidence Factor, if unknown[1237]

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 Factor[1238]

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

[1237] 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0, Volume 2: Commercial and Industrial Measures.

[1238] 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).

A. RETIRED

Verification.

Coordination with Other Savings Assessment Activities

Although the TRM will be a critically important tool for both DSM planning and estimation of actual savings, it will not, by itself, ensure that reported savings are the same as actual savings. There are two principal reasons for this:

1. **The TRM itself does not ensure appropriate estimation of savings**. One of the responsibilities of the Independent Program Evaluators will be to assess that the TRM has been used appropriately in the calculation of savings.
2. **The TRM may have assumptions or protocols that new information suggests are outdated**. New information that could inform the reasonableness of TRM assumptions or protocols can surface at any time, but they are particularly common as local evaluations or annual savings verification processes are completed. Obviously, the TRM should be updated to reflect such new information. However, it is highly likely that some such adjustments will be made too late to affect the annual savings estimate of a program administrator for the previous year. Thus, there may be a difference between savings estimates in annual compliance reports and the “actual savings” that may be considered acceptable from a regulatory perspective. However, such updates should be captured in as timely a fashion as possible.

These two issues highlight the fact that the TRM needs to be integrated into a broader process that has two other key components: an annual savings verification process and on-going evaluation.

In our view, an annual savings verification process should have several key features.

1. It should include a review of data tracking systems used to record information on efficiency measures that have been installed. Among other things, this review should assess whether data appear to have been appropriately and accurately entered into the system.
2. It should include a review of all deemed savings assumptions underlying the program administrators’ savings claims to ensure that they are consistent with the TRM.
3. It should include a detailed review of a statistically valid, random sample of custom commercial and industrial projects to ensure that custom savings protocols were appropriately applied. At a minimum, engineering reviews should be conducted; ideally, custom project reviews should involve some on-site assessments as well.
4. These reviews should be conducted by an independent organization with appropriate expertise.

5. The participants will need to have a process in place for quickly resolving any disputes between the utilities or program administrators on the one hand and the independent reviewer on the other.
6. The results of the independent review and the resolution of any disagreements should ideally be very transparent to stakeholders.

Such verification ensures that information is being tracked accurately and in a manner consistent with the TRM. However, as important as it is, verification does not ensure that reported savings are “actual savings”. TRMs are never and can never be perfect. Even when the verification process documents that assumptions have been appropriately applied, it can also highlight questions that warrant future analysis that may lead to changes to the TRM. Put another way, evaluation studies are and always will be necessary to identify changes that need to be made to the TRM. Therefore, in addition to annual savings verification processes, evaluations will periodically be made to assess or update the underlying assumption values for critical components of important measure characterizations.

In summary, there should be a strong, sometimes cyclical relationship between the TRM development and update process, annual compliance reports, savings verification processes, and evaluations. As such, we recommend coordinating these activities.

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

D. Commercial & Industrial Lighting Operating Hours and Coincidence Factors

Downstream Programs[1239]

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 form 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 form 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 Type[1240]

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
Education	Office (Executive/Private)	2,084	0.42	0.57	0.26
Education	Office (General)	4,252	0.66	0.67	0.46

[1239] Downstream programs are programs where the efficiency program's influence is at the end user level such as prescriptive, custom, or new construction programs.

[1240] 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}	$CF_{PJM\text{-}S}$	$CF_{PJM\text{-}W}$
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
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

Building Type	Space Type	HOURS	CF_{UPeak}	CF_{PJM-S}	CF_{PJM-W}
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

Table D-2: C&I Downstream Lighting Parameters by Space Type for Unknown or Unmatched Building Types[1241]

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
All	Office (General)	3,001	0.67	0.67	0.43
All	Office(Open Plan)	3,159	0.81	0.82	0.49

[1241] 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}
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
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

E. Commercial & Industrial Lighting Waste Heat Factors

Waste Heat Factors for C&I Lighting – Known HVAC Types[1242]

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[1243]
Maryland, BGE	Office	1.36	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	1.23	1.24	1.02	0.75	0.89	0.73
	Other	1.35	1.33	1.08	0.82	0.93	0.74
Maryland, SMECO	Office	1.36	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	1.23	1.25	1.02	0.75	0.89	0.73
	Other	1.35	1.33	1.08	0.82	0.93	0.74
Maryland, Pepco	Office	1.36	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	1.23	1.25	1.02	0.75	0.89	0.73
	Other	1.35	1.33	1.08	0.82	0.93	0.74
Maryland, DPL	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

[1242] 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.

[1243] Waste Heat Factors for “NoAC/ElecRes” estimated as at difference between “AC/ElecRes” and “AC/NonElec” plus one.

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[1243]
	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
Maryland, Potomac Edison	Office	1.34	1.31	1.10	0.85	0.94	0.75
	Retail	1.27	1.25	1.06	0.83	0.95	0.77
	School	1.45	1.45	1.10	0.81	0.96	0.71
	Warehouse	1.2	1.21	1.02	0.75	0.89	0.73
	Other	1.33	1.31	1.08	0.82	0.93	0.74
Washington, D.C., All	Office	1.36	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	1.23	1.25	1.02	0.75	0.89	0.73
	Other	1.35	1.33	1.08	0.82	0.93	0.74
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.

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 ($HOURS_{COOL}$)[1244]

Space and/or Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	937	922	945	861	1,103	909	1,143
Education - Community College	713	701	718	655	839	691	869
Education - Primary School	293	288	295	269	344	284	357
Education - Relocatable Classroom	348	342	351	319	409	337	424
Education - Secondary School	337	331	340	309	396	327	411
Education - University	787	774	793	723	926	763	960
Grocery	672	662	678	618	791	652	820
Health/Medical - Hospital	1,213	1,194	1,223	1,114	1,427	1,176	1,480
Health/Medical - Nursing Home	645	634	650	592	758	625	786
Lodging - Hotel	1,816	1,787	1,831	1,668	2,137	1,760	2,215
Manufacturing – Bio Tech/High Tech	867	853	874	796	1,020	840	1,057
Manufacturing – 1 Shift/Light Industrial	456	449	460	419	537	442	557
Multi-Family (Common Areas)	1,509	1,485	1,521	1,386	1,776	1,463	1,841
Office - Large	727	716	733	668	856	705	887
Office - Small	629	619	634	577	740	609	767
Restaurant - Fast-Food	724	712	730	665	851	701	883
Restaurant - Sit-Down	762	750	768	700	897	739	930
Retail - Multistory Large	880	866	887	808	1,035	853	1,074
Retail - Single-Story Large	904	890	911	830	1,064	876	1,103
Retail - Small	915	901	923	840	1,077	887	1,116
Storage - Conditioned	243	239	245	223	286	235	296
Warehouse - Refrigerated	3,886	3,824	3,917	3,569	4,572	3,767	4,740

[1244] 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.

Full Load Heating Hours by Location and Building Type ($\text{HOURS}_{\text{HEAT}}$)[1245]

Space and/or Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	1,114	1,150	1,114	1,168	1,064	1,079	1,040
Education - Community College	713	736	713	747	681	691	666
Education - Primary School	668	689	668	700	638	647	623
Education - Relocatable Classroom	647	668	647	679	618	627	604
Education - Secondary School	719	742	719	754	687	697	671
Education - University	530	546	530	555	506	513	494
Grocery	984	1,015	984	1,031	939	953	918
Health/Medical - Hospital	214	221	214	224	204	207	200
Health/Medical - Nursing Home	932	962	932	977	890	903	870
Lodging - Hotel	2,242	2,313	2,242	2,350	2,140	2,172	2,092
Manufacturing – Bio Tech/High Tech	146	151	146	153	139	141	136
Manufacturing – 1 Shift/Light Industrial	585	603	585	613	558	567	546
Multi-Family (Common Areas)	256	264	256	268	244	248	239
Office - Large	221	228	221	231	211	214	206
Office - Small	440	454	440	461	420	426	411
Restaurant - Fast-Food	1,226	1,265	1,226	1,285	1,170	1,188	1,144
Restaurant - Sit-Down	1,131	1,167	1,131	1,185	1,079	1,096	1,055
Retail - Multistory Large	591	609	591	619	564	572	551
Retail - Single-Story Large	739	762	739	774	705	716	689
Retail - Small	622	642	623	652	594	603	581
Storage - Conditioned	854	881	854	895	815	828	797
Warehouse - Refrigerated	342	353	343	359	327	332	320

[1245] 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.

G. Summary of updates from previous version

Mid-Atlantic TRM v9 Summary of updated values and assumptions

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
RESIDENTIAL MARKET SECTOR											
Lighting											
	Solid State Lighting (LED) Recessed Downlight Luminaire							X		X	
	ENERGY STAR Integrated Screw Based SSL (LED) Lamp			X				X		X	
	Occupancy Sensor – Wall-Mounted										
	Connected Lighting										
Refrigeration											
	Freezer										Misplaced entry deleted
	Refrigerator, Time of Sale										
	Refrigerator, Early Replacement										
	Refrigerator and Freezer, Early Retirement										

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Heating Ventilation and Air Conditioning (HVAC)											
	Central Furnace Efficient Fan Motor										
	Room Air Conditioner, Time of Sale										
	ENERGY STAR Central A/C										
	Air Source Heat Pump										
	Packaged Terminal Air Conditioners (PTAC) and Heat Pumps (PTHP)										
	Duct Sealing										
	Ductless Mini-Split Heat Pump										
	HE Gas Boiler										
	Condensing Furnace (gas)										
	Smart Thermostat										
	Room Air Conditioner, Early Replacement										
	Room Air Conditioner, Early Retirement / Recycling										
	Boiler Pipe Insulation										
	Boiler Reset Controls										
	Ground Source Heat Pumps										

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
	High Efficiency Bathroom Exhaust Fan										
	ENERGY STAR Ceiling Fan										
Domestic Hot Water (DHW)											
	Low Flow Shower Head					X					
	Faucet Aerators				X	X	X				
	Domestic Hot Water Tank Wrap										
	DHW Pipe Insulation										
	High Efficiency Gas Water Heater										
	Heat Pump Domestic Water Heater		X	X	X	X		X			
	Thermostatic Restrictor Shower Valve										
	Water Heater Temperature Setback										
Appliance											
	Clothes Washer										
	Clothes Washer, Early Replacement										
	Dehumidifier		X	X	X	X					
	Dehumidifier, Early Retirement / Recycling										
	ENERGY STAR Air Purifier/Cleaner										
	Clothes Dryer										
	Dishwasher										

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Shell Savings											
	Air sealing										
	Attic/ceiling/roof insulation										
	Efficient Windows - Energy Star, Time of Sale										
	Crawl Space Insulation and Encapsulation										
	Residential Retrofit Comprehensive Insulation and Air-Sealing	X									
	Residential New Construction Comprehensive Thermal Improvements	X									
Pool Pump											
	Pool pump-two speed										
	Pool pump-variable speed										
Plug Load											
	Tier 1 Advanced Power Strip										
	Freezer										
	Clothes Dryer										
	Room Air Conditioners (Upstream)										

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Retail Products											
	ENERGY STAR Soundbar										
	ENERGY STAR Air Cleaner										
	ENERGY STAR Desktop Computer										
	ENERGY STAR Laptop Computer										
	ENERGY STAR Computer Monitor										
	ENERGY STAR Television										

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
COMMERCIAL & INDUSTRIAL MARKET SECTOR											
Lighting											
	LED Exit Sign										
	Solid State Lighting (LED) Recessed Downlight Luminaire										
	Delamping										
	Occupancy Sensor – Wall-, Fixture-, or Remote-Mounted										
	Daylight Dimming Control										
	Advanced Lighting Design – Commercial										
	LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Luminaires and Retrofit Kits										
	LED High-Bay Luminaires and Retrofit Kits										
	LED High-Intensity Discharge Screw Base										
	LED 1x4, 2x2, and 2x4 Luminaires and Retrofit Kits										

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
	LED Parking Garage/Canopy Luminaires and Retrofit Kits										
	ENERGY STAR Integrated Screw Based SSL (LED) Lamp – Commercial										
	LED Four-pin based Lamp – Commercial										
	LED Refrigerated Case Lighting										
	Exterior LED Flood and Spot Luminaires										
	Low Wattage Four-Foot Linear Fluorescent Replacement Lamps										
	LED Four-Foot Linear Replacement Lamps										
	Networked Lighting Controls	X									

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Heating Ventilation and Air Conditioning (HVAC)											
	Unitary HVAC Systems										
	Ductless Mini-Split Heat Pump (DMSHP)				X						
	Variable Frequency Drive (VFD) for HVAC										
	Electric Chillers										
	Gas Boiler										
	Gas Furnace										
	Dual Enthalpy Economizer										
	AC Tune-Up				X						
	Smart Thermostat										
	Variable Refrigerant Flow (VRF) Heat Pump Systems	X									
	Steam Boiler Traps – Repair/Replace	X									
	Boiler Reset and Cut-Out Controls	X									
	Commercial Gas Furnace ≥225,000 BTU/h	X									
	Infrared Heaters	X									

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Refrigeration											
	ENERGY STAR Commercial Freezers		X	X	X	X		X			
	ENERGY STAR Commercial Refrigerator		X	X	X	X		X	X		
	Night Covers for Refrigerated Cases										
	Anti-Sweat Heater Controls										
	Evaporator Fan Electronically-Commutated Motor (ECM) Retrofit										
	Evaporator Fan Motor Controls										
	Refrigeration Door Gasket Replacement	X									
Hot Water											
	C&I Heat Pump Water Heater										
	Pre-Rinse Spray Valves										
	High Efficiency Commercial Gas Storage Water Heater >75kBtu	X									
	High Efficiency Commercial Gas Storage Water Heater ≤75kBtu	X									

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Appliance											
	Commercial Clothes Washer										
Plug Load											
	Tier 1 Advanced Power Strip										
Commercial Kitchen Equipment											
	Commercial Fryers										
	Commercial Steam Cookers										
	Commercial Hot Food Holding Cabinets										
	Commercial Griddles										
	Commercial Convection Ovens		X		X						
	Commercial Combination Ovens		X		X						
	ENERGY STAR Commercial Rack Oven	X									
	Commercial Conveyor Oven	X									
	Commercial Ice Makers	X									
	Commercial Dishwashers	X									
	Demand Control Commercial Kitchen Ventilation	X									

End use	Measure	New	Efficient	Baseline	Energy	Demand	Water	Costs	Lifetime	O&M	Other
Industrial Equipment											
	Variable Speed Drive Screw Air Compressors	X									