



Northeast Energy Efficiency Partnerships



MID-ATLANTIC TECHNICAL REFERENCE MANUAL VERSION 7.0

Final Draft

May 2017



NEEP was founded in 1996 as a non-profit whose mission is to serve the Northeast and Mid-Atlantic to accelerate energy efficiency in the building sector through public policy, program strategies and education. Our vision is that the region will fully embrace energy efficiency as a cornerstone of sustainable energy policy to help achieve a cleaner environment and a more reliable and affordable energy system.

The Regional Evaluation, Measurement and Verification Forum (EM&V Forum or Forum) is a project facilitated by Northeast Energy Efficiency Partnerships, Inc. (NEEP). The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track, and report energy efficiency and other demand resource savings, costs, and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast, New York, and the Mid-Atlantic region. The Mid-Atlantic Technical Reference Manual is a project that originated in the EM&V Forum.

About Shelter Analytics



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

MID-ATLANTIC TECHNICAL REFERENCE MANUAL VERSION 7.0/May 2017

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Northeast Energy Efficiency Partnerships

MID-ATLANTIC TECHNICAL REFERENCE MANUAL VERSION 7.0

A Project of the Regional Evaluation, Measurement and Verification Forum

May 2017

Prepared by Shelter Analytics

Facilitated and Managed by Northeast Energy Efficiency Partnerships



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PREFACE

The Regional EM&V Forum

The Regional EM&V Forum is a project managed and facilitated by Northeast Energy Efficiency Partnerships, Inc. The Forum's purpose is to provide a framework for the development and use of common and/or consistent protocols to measure, verify, track and report energy efficiency and other demand resource savings, costs and emission impacts to support the role and credibility of these resources in current and emerging energy and environmental policies and markets in the Northeast and the Mid-Atlantic region. For more information, see <http://www.neep.org/emv-forum>. The Mid-Atlantic TRM is a project that originated in the Regional EM&V Forum.

Acknowledgements

This update of the Mid-Atlantic Technical Reference Manual (TRM) was prepared by Shelter Analytics. Bret Hamilton, project manager, was assisted by Matt Socks and Cliff McDonald of Optimal Energy, Inc.

Subcommittee for the Mid-Atlantic TRM

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INTRODUCTION

This update to the Technical Reference Manual is the outcome of a project conducted for the Regional Evaluation, Measurement and Verification Forum ('the EMV Forum') sponsored by Maryland, Delaware and the District of Columbia. The intent of the project was to develop and document in detail common assumptions for approximately thirty prescriptive residential and commercial/industrial electric energy efficiency measures savings. For each measure, the TRM includes either specific deemed values or algorithms² for calculating:

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

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

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

¹ While the District of Columbia did not financially support this update, subcommittee members from this jurisdiction volunteered time to participate in the scoping of this update and in discussion of future updates.

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

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 seventh generation (sixth update) 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 Deemed 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, local, primary research and data, and information that was developed for the EMV Forum Product “A2” (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 Intended Uses 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 other assumptions are based on mid-Atlantic data. However, a number of assumptions – including assumptions regarding peak coincidence factors – are based on sources from other regions, often adjusted for climate or other known regional differences.
- While this information is not perfectly transferable, due to differences in definitions of peak periods as well as geography, climate and customer mix, it was used because it was the most transferable and usable source available at the time.³
- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and transparently, and they are widely accepted in the industry. Unlike simulation

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

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

- For some of the whole-building program designs that are being planned or implemented in 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)	<p><u>Definition:</u> 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 construction characterization isn't explicitly provided, the TOS characterization is typically appropriate.</p> <p><u>Baseline</u> = New standard efficiency or code compliant equipment.</p> <p><u>Efficient Case</u> = New, premium efficiency equipment above federal and state codes and standard industry practice.</p> <p><u>Example:</u> Appliance rebate</p>
New Construction (NC)	<p><u>Definition:</u> A program that intervenes during building design to support the use of more-efficient equipment and construction practices.</p> <p><u>Baseline</u> = Building code or federal standards.</p> <p><u>Efficient Case</u> = The program's level of building specification</p>

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



Baseline Condition	Attributes
	<u>Example:</u> Building shell and mechanical measures
Retrofit (RF)	<u>Definition:</u> A program that <i>upgrades</i> or enhances existing equipment. <u>Baseline</u> = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life. <u>Efficient Case</u> = Post-retrofit efficiency of equipment. <u>Example:</u> Air sealing, insulation, and controls.
Early Replacement (EREP)	<u>Definition:</u> A program that <i>replaces</i> existing, operational equipment. ⁵ <u>Baseline</u> = Dual; it begins as the existing equipment and shifts to new baseline equipment after the remaining life of the existing equipment is over. <u>Efficient Case</u> = New, premium efficiency equipment above federal and state codes and standard industry practice. <u>Example:</u> Refrigerators and freezers.
Early Retirement (ERET)	<u>Definition:</u> A program that <i>retires</i> inefficient, operational duplicative equipment or inefficient equipment that might otherwise be resold. <u>Baseline</u> = The existing equipment, which is retired and not replaced. <u>Efficient Case</u> = Assumes zero consumption since the unit is retired. <u>Example:</u> Appliance recycling.
Direct Install (DI)	<u>Definition:</u> A program where measures are installed during a site visit. <u>Baseline</u> = Existing equipment. <u>Efficient Case</u> = New, premium efficiency equipment above federal and state codes and standard industry practice. <u>Example:</u> Lighting and low-flow hot water measures

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.

Time of Sale and New Construction Incremental Costs

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

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 7.0 Incremental Costs Update, 2017 at:

<http://www.neep.org/file/5548/download?token=pLIMjfvz>, and
http://www.neep.org/file/5549/download?token=S3weM_MA

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



RESIDENTIAL MARKET SECTOR

Lighting End Use

Solid State Lighting (LED) Recessed Downlight Luminaire

Unique Measure Code: RS_LT_TOS_SSLEDWN_0415, RS_LT_EREP_SSLEDWN_0415

Effective Date: June 2015

End Date: TBD

Measure Description

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

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

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

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

⁶ ENERGY STAR specification can be viewed here:

<https://www.energystar.gov/sites/default/files/asset/document/Luminaires%20V2%200%20Final.pdf>



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

Where:

WattsBase = Connected load of baseline lamp
= Actual if early replacement, if LED lumens is known – find the equivalent baseline wattage from the table below⁷, if unknown assume 65W⁸

Lower Lumen Range	Upper Lumen Range	WattsBase	Baseline Shift ≥90 CRI	Baseline Shift <90 CRI
400	449	40	7%	10%
450	499	45	7%	10%
500	649	50	9%	12%
650	1419	65	13%	16%

WattsEE = Connected load of efficient lamp

= Actual. If unknown assume 9.2W⁹

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

= 1.0¹⁰

HOURS = Average hours of use per year

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	2.52	920 ¹¹
Multi Family Common Areas	16.3	5,950 ¹²

⁷ Based on ENERGY STAR equivalence table; http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumens

⁸ Baseline wattage based on common 65 Watt BR30 incandescent bulb (e.g. <http://www.destinationlighting.com/storeitem.jhtml?iid=16926>)

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

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

¹¹ Based on Navigant Consulting, “EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study” March 27, 2017, page 13. This assumption is a product of metered CFLs and LEDs. To date there has not been sufficient data available to provide a separate LED hours assumption, and this should be reviewed in future years.

¹² Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. This estimate is



Installation Location	Daily Hours	Annual Hours
Unknown	2.52	920

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

	$WHFe_{Cool}$
Building with cooling	1.087 ¹³
Building without cooling or exterior	1.0
Unknown	1.077 ¹⁴

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

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

If unknown assume 0.899¹⁵

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

= 47%¹⁶ for interior or unknown location

= 0% for exterior or unheated location

η_{Heat} = Efficiency in COP of Heating equipment
= actual. If not available, use¹⁷:

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.

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

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

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

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



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

%ElecHeat = Percentage of home with electric heat

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5% ¹⁹

Illustrative example – do not use as default assumption

Residential interior and in-unit Multi Family

$$\Delta \text{kWh} = ((65 - 9.2) / 1,000) * 1.0 * 920 * (0.899 + (1.077 - 1))$$

$$= 50.1 \text{ kWh}$$

Multi Family Common Areas

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

$$= 324 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

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

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

¹⁹ Based on KEMA baseline study for Maryland.



Where:

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

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

CF = Summer Peak Coincidence Factor for measure

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.0825 ²²
	PJM CF	0.084 ²³
Multi Family Common Areas	PJM CF	0.43 ²⁴
Unknown	Utility Peak CF	0.0825
	PJM CF	0.084

Illustrative example – do not use as default assumption

$$\Delta kW_{PJM} = ((65 - 9.2) / 1,000) * 1.0 * 1.17 * 0.084$$

$$= 0.0055 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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

$$\Delta \text{MMBtuPenalty}^{25} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF} *)$$

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

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

²² Based on Navigant Consulting "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" March 27, 2017, page 15.

²³ Ibid.

²⁴ Consistent with "Lodging Common Area" coincidence factor in Commercial Screw base CFL measure characterization, based on 'Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010'.

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



$$0.003412) / \eta_{\text{Heat}}) * \%FossilHeat$$

Where:

<i>HF</i>	<i>= Heating Factor or percentage of light savings that must be heated</i> <i>= 47%²⁶ for interior or unknown location</i> <i>= 0% for exterior or unheated location</i>
<i>0.003412</i>	<i>= Converts kWh to MMBtu</i>
<i>η_{Heat}</i>	<i>= Efficiency of heating system</i> <i>= 80%²⁷</i>
<i>%FossilHeat</i>	<i>= Percentage of home with non-electric heat</i>

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5% ²⁸

Illustrative example – do not use as default assumption

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

$$\begin{aligned}\Delta \text{MMBtuPenalty} &= - (((65 - 9.2)/1000) * 1.0 * 898 * 0.47 * 0.003412/0.75) * \\ &1.0 \\ &= - 0.11 \text{ MMBtu}\end{aligned}$$

If home heating fuel is unknown:

$$\begin{aligned}\Delta \text{MMBtuPenalty} &= - (((65 - 9.2)/1000) * 1.0 * 898 * 0.47 * 0.003412/0.80) * \\ &0.625 \\ &= - 0.063 \text{ MMBtu}\end{aligned}$$

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

²⁷ Minimum federal standard for residential furnaces.

²⁸ Based on KEMA baseline study for Maryland.

Annual Water Savings Algorithm

n/a

Baseline Adjustment

To account for new EISA standards taking effect in 2020, the savings for this measure should be reduced to account for the higher baselines. The “WattsBase” table above shows the calculated adjustments. The calculated energy savings for the applicable lamp should be multiplied by the appropriate factor from the table for years 2020 and beyond²⁹.

Incremental Cost

The lifecycle NPV incremental cost for time of sale replacements is \$4.55, based on a baseline incandescent BR lamp cost of \$3.65 and an LED BR Lamp cost of \$8.20.³⁰ Early replacements should use the full installed cost of \$8.20.

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.³¹

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

²⁹ See ‘ESTAR Integrated Screw SSL Lamp_032014.xls’ for details. The Minimum Lamp Efficacy Requirements in ENERGY STAR Product Specification for Lamps (Light Bulbs) V2.0 vary by Color Rendering Index (CRI).

³⁰ Cost assumptions are adapted from 2016 4th Quarter 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, 2016, for the Maryland and U.S. markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2016, Nielsen.

³¹ The ENERGY STAR Spec for SSL Recessed Downlights requires luminaires to maintain $\geq 70\%$ initial light output for 25,000 hrs in an indoor application for separable luminaires and 50,000 for inseparable luminaires. Measure life is capped at 20 years.



	BR-type Incandescent
Replacement Cost	\$3.65
Component Life ³² (years) Residential interior and in-unit Multi Family or unknown.	2.17 ³³
Multi Family Common Areas	0.34 ³⁴

The calculated net present value of the baseline replacement costs is \$18.69 for Residential interior and in-unit Multi Family \$70 for downlights installed in Multifamily common areas.

³² Based on lamp life / assumed annual run hours.

³³ Assumes rated life of BR incandescent bulb of 2000 hours, based on product review. Lamp life is therefore $2000/920 = 2.17$ years.

³⁴ Calculated as $2000/5950 = 0.34$ years.



ENERGY STAR Integrated Screw Based SSL (LED) Lamp

Unique Measure Code: RS_LT_TOS_SSLEDWN_0516, RS_LT_EREP_SSLEDWN_0516

Effective Date: May 2016

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 socket³⁵. 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

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

Where:

WattsBase = Based on lumens of the LED – find the equivalent baseline wattage from the table below. The table also

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



shows the baseline shift from the EISA standards taking effect in 2020. See the section on baseline shift for how to apply the adjustment.

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase	Baseline Shift ≥ 90 CRI	Baseline Shift < 90 CRI
Standard A-Type (medium-base)	250	449	25	14%	16%
	450	799	29	25%	29%
	800	1099	43	26%	30%
	1100	1599	53	32%	36%
	1600	1999	72	31%	35%
	2000	2599	72	47%	52%
	2600	3000	150	20%	24%
	3001	5279	200	19%	22%
	5280	6000	300	17%	20%
Decorative (medium-base, > 499 lumens)	500	1050	43	17%	17%
Globe (medium-base, > 499 lumens)	500	574	43	11%	11%
	575	649	53	10%	10%
	650	1099	72	10%	10%
	1100	1300	150	6%	6%
3-Way, bug, marine, rough service, infrared	250	449	25	12%	12%
	450	799	40	14%	14%
	800	1099	60	14%	14%
	1100	1599	75	17%	17%
	1600	1999	100	17%	17%
	2000	2549	125	17%	17%
	2550	2999	150	18%	18%
Globe (any base, < 500 lumens)	90	179	10	12%	12%
	180	249	15	13%	13%
	250	349	25	10%	10%
	350	499	40	9%	9%
Globe (candelabra or intermediate base, ≥ 500 lumens)	500	574	60	7%	7%
	575	649	75	6%	6%
	650	1099	100	7%	7%
	1100	1300	150	6%	6%
Decorative (Shapes B, BA, C, CA, DC, F, G, any base, < 500 lumens)	70	89	10	6%	6%
	90	149	15	6%	6%
	150	299	25	7%	7%



	300	500	40	8%	8%
Decorative (candelabra or intermediate base, ≥ 500 lumens)	500	1050	60	11%	11%
Reflector with medium screw bases w/ diameter ≤2.25"	400	449	40	7%	10%
	450	499	45	7%	10%
	500	649	50	8%	11%
	650	1199	65	11%	14%
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)	640	739	40	14%	18%
	740	849	45	14%	19%
	850	1179	50	18%	23%
	1180	1419	65	17%	22%
	1420	1789	75	19%	24%
	1790	2049	90	19%	24%
	2050	2579	100	22%	27%
	2580	3429	120	25%	31%
	3430	4270	150	26%	32%
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	11%	15%
	630	719	45	12%	15%
	720	999	50	14%	18%
	1000	1199	65	14%	18%
	1200	1519	75	15%	19%
	1520	1729	90	15%	19%
	1730	2189	100	17%	22%
	2190	2899	120	19%	24%
	2900	3850	150	21%	26%
*ER30, BR30, BR40, or ER40	400	449	40	7%	10%
	450	499	45	7%	10%
	500	649-1179	50	9%	12%
*BR30, BR40, or ER40	650	1419	65	13%	16%
*R20	400	449	40	7%	10%
	450	719	45	10%	13%
*All reflector lamps below lumen ranges specified above	200	299	20	9%	12%
	300	399-639	30	10%	13%

WattsEE

ISR

= Actual LED wattage

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

= 0.98³⁶

³⁶ 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



HOURS = Average hours of use per year

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	2.52	920 ³⁷
Multi Family Common Areas	16.3	5,950 ³⁸
Exterior	4.5	1,643 ³⁹
Unknown	2.52	920 ⁴⁰

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 ⁴¹
Building without cooling or exterior	1.0
Unknown	1.077 ⁴²

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 $0.90 + 0.045 * 0.95 + 0.045 * 0.95^2 = 0.98$

³⁷ Based on Navigant Consulting, "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" March 27, 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.

³⁸ 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.

³⁹ 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

⁴⁰ "Unknown" assumes a residential interior or in-unit multifamily application.

⁴¹ 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).

⁴² 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.).



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

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

If unknown assume 0.899⁴³

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

= 47%⁴⁴ for interior or unknown location

= 0% for exterior or unheated location

η_{Heat} = Efficiency in COP of Heating equipment
= actual. If not available, use⁴⁵:

System Type	Age of Equipment	HSPF Estimate	η_{Heat} (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	2006 - 2014	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.74 ⁴⁶

$\%ElecHeat$ = Percentage of home with electric heat

Heating fuel	$\%ElecHeat$
Electric	100%
Fossil Fuel	0%

⁴³ Calculated using defaults; $1 + ((0.47/1.74) * 0.375) = 0.899$

⁴⁴ 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.

⁴⁵ 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.

⁴⁶ 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.



Unknown	37.5% ⁴⁷
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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.

$$\begin{aligned}\Delta\text{kWh} &= ((50 - 10) / 1,000) * 0.98 * 920 * (0.899 + (1.077 - 1)) \\ &= 35.2 \text{ kWh}\end{aligned}$$

Baseline Adjustment

To account for new EISA standards going into effect in 2020, the savings for this measure should be reduced to account for the higher baselines. The baseline watts table above shows the calculated adjustments. The calculated energy savings for the applicable lamp should be multiplied by the appropriate factor from the baseline watts table for years 2020 and beyond⁴⁸.

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

	WHFd
Building with cooling	1.19 ⁴⁹
Building without cooling or exterior	1.0
Unknown	1.17 ⁵⁰

⁴⁷ Based on KEMA baseline study for Maryland.

⁴⁸ See 'ESTAR Integrated Screw SSL Lamp_032014.xls' for details. The Minimum Lamp Efficacy Requirements in ENERGY STAR Product Specification for Lamps (Light Bulbs) V2.0 vary by Color Rendering Index (CRI).

⁴⁹ 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).

⁵⁰ 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	0.0825 ⁵¹
	PJM CF	0.084 ⁵²
Multi Family Common Areas	PJM CF	0.43 ⁵³
Exterior	PJM CF	0.018 ⁵⁴
Unknown	Utility Peak CF	0.0825
	PJM CF	0.084

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.

$$\begin{aligned}\Delta kW_{PJM} &= ((50 - 10) / 1,000) * 0.98 * 1.17 * 0.084 \\ &= 0.0039 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

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

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

Where:

$$\begin{aligned}\text{HF} &= \text{Heating Factor or percentage of light savings that must be heated} \\ &= 47\%^{55} \text{ for interior or unknown location}\end{aligned}$$

⁵¹ Based on Navigant Consulting "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" March 27, 2017, page 15

⁵² Ibid.

⁵³ Consistent with "Lodging Common Area" coincidence factor in Commercial Screw base CFL measure characterization, based on 'Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010'.

⁵⁴ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.



0.003412 = 0% for exterior or unheated location
 = Converts kWh to MMBtu
 η_{Heat} = Efficiency of heating system
 = 80%⁵⁶
 $\%FossilHeat$ = Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5% ⁵⁷

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.

$$\Delta \text{MMBtuPenalty} = - ((50 - 10) / 1,000) * 0.98 * 898 * 0.47 * 0.003412 / 0.80 * 0.625$$

$$= - 0.044 \text{ MMBtu}$$

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.⁵⁸

Category	Time of Sale Incremental Cost
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⁵⁵ 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.

⁵⁶ Minimum federal standard for residential furnaces.

⁵⁷ Based on KEMA baseline study for Maryland.

⁵⁸ Cost assumptions are adapted from 2016 4th Quarter 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, 2016, for the Maryland and U.S. markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2016, Nielsen. IMC values represent 2017\$



Category	Time of Sale Incremental Cost
Unknown	\$2.54
Globe	\$5.76
Reflector	\$3.52
A Lamp	\$3.85
Candelabra	\$5.42

Measure Life

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

Measure Life, Energy Star V2.0					
	Rated Life ⁵⁹	Residential interior, in-unit Multi Family or unknown	Multi Family Common Areas	Exterior	Unknown
Omnidirectional	15,000	16.3	2.5	9.1	13.6
Decorative	15,000	16.3	2.5	9.1	13.6
Directional	15,000 ⁶⁰	16.3	2.5	9.1	13.6

Operation and Maintenance Impacts

To account for the shift in baseline due to the Federal Legislation, the leveled baseline replacement cost over the lifetime of the LED is calculated (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	\$1.52	\$1.79
Replacement Cost, Globe	\$1.58	\$2.17
Replacement Cost, Reflector	\$3.63	\$4.68
Replacement Cost, A Lamp	\$1.87	\$1.71

⁵⁹ 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.

⁶⁰ The proposed ENERGY STAR V2.1 specifications will reduce rated life requirements to 15,000 hours for directional lamps. This revision has not yet been finalized, but finalization is expected shortly after the TRM publication date. Should the final published V2.1 specification differ from this assumption, the TRM will be revised



	EISA 2012-2014 Compliant	EISA 2020 Compliant
Replacement Cost, Candelabra	\$1.09	\$1.71
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	\$0.68	\$10.26	\$1.52
Globe	\$0.78	\$10.66	\$1.71
Reflector	\$1.71	\$24.50	\$3.81
A Lamp	\$0.71	\$12.62	\$1.67
Candelabra	\$0.59	\$7.36	\$1.27



Refrigeration End Use

Freezer

Unique Measure Code(s): RS_RF_TOS_FREEZER_0414

Effective Date: June 2014

End Date: TBD

Measure Description

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 $1.73 \times \text{Total Volume}$):⁶¹

Product Category	Volume (cubic feet)	Federal Baseline Maximum Energy Usage in kWh/year ⁶²	ENERGY STAR Maximum Energy Usage in kWh/year ⁶³
Upright Freezers with Manual Defrost	7.75 or greater	$5.57 \times \text{AV} + 193.7$	$5.01 \times \text{AV} + 174.3$
Upright Freezers with Automatic Defrost	7.75 or greater	$8.62 \times \text{AV} + 228.3$	$7.76 \times \text{AV} + 205.5$
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	$7.29 \times \text{AV} + 107.8$	$6.56 \times \text{AV} + 97.0$
Compact Upright Freezers with Manual Defrost	< 7.75 and ≤ 36 inches in height	$8.65 \times \text{AV} + 225.7$	$7.79 \times \text{AV} + 203.1$
Compact Upright Freezers with Automatic Defrost	< 7.75 and ≤ 36 inches in height	$10.17 \times \text{AV} + 351.9$	$9.15 \times \text{AV} + 316.7$
Compact Chest Freezers	< 7.75 and ≤ 36 inches	$9.25 \times \text{AV} + 136.8$	$8.33 \times \text{AV} + 123.1$

⁶¹ http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746

⁶² http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

⁶³

<http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Specification.pdf>



	in height		
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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 size and configuration of the freezer (chest freezer or upright freezer, automatic or manual defrost) 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 defined below and calculated above:

Equipment	Volume	Criteria
Full Size Freezer	7.75 cubic feet or greater	At least 10% more energy efficient than the minimum federal government standard (NAECA).
Compact Freezer	Less than 7.75 cubic feet and 36 inches or less in height	At least 10% more energy efficient than the minimum federal government standard (NAECA).

Annual Energy Savings Algorithm

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

Where:

kWh_{BASE} = Baseline kWh consumption per year as calculated in algorithm provided in table above.

kWh_{ESTAR} = ENERGY STAR kWh consumption per year as calculated in algorithm provided in table above.

Illustrative example – do not use as default assumption

A 12 cubic foot Upright Freezer with Manual Defrost:

$$\Delta kWh = (5.57 * (12 * 1.73) + 193.7) - (5.01 * (12 * 1.73) + 174.3)$$



$$= 309.3 - 278.3$$

$$= 31.0 \text{ kWh}$$

If volume is unknown, use the following default values, which gives a total savings of 41.2 kWh:

Product Category	Volume Used ⁶⁴	kWh _{BASE}	kWh _{ESTAR}	kWh Savings	Weighting if product category unknown ⁶⁵
Upright Freezers with Automatic Defrost	27.9	469.0	422.2	46.8	39.5%
Chest Freezers and all other Freezers except Compact Freezers	27.9	311.4	280.2	31.2	40.5%
Compact Upright Freezers with Manual Defrost	10.4	467.2	420.6	46.6	10.0%
Compact Upright Freezers with Automatic Defrost	10.4	635.9	572.2	63.7	6.0%
Compact Chest Freezers	10.4	395.1	355.7	39.4	4.0%

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23⁶⁶

⁶⁴ Volume is based on ENERGY STAR Calculator assumption of 16.14 ft³ average volume, converted to Adjusted volume by multiplying by 1.73.

⁶⁵ Unknown configuration is based upon a weighted average of the different configurations. Data is taken from the DOE Technical Support Document (http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf). Weighting based on 80% Standard v 20% Compact (2007 annual shipments p3-26) and product class market shares from pages 9-17 and 9-24. See 'Freezer default calcs.xls' for more details.

⁶⁶ 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



LSAF = Load Shape Adjustment Factor
= 1.15⁶⁷

Illustrative example – do not use as default assumption
A 12 cubic foot Upright Freezer with Manual Defrost:

$$\Delta \text{kW} = 31.0 / 8760 * 1.23 * 1.15$$
$$= 0.005 \text{ kW}$$

If volume is unknown, use the following default values:

Product Category	Assumptions after September 2014
	kW Savings
Upright Freezers with Manual Defrost	0.0057
Upright Freezers with Automatic Defrost	0.0076
Chest Freezers and all other Freezers except Compact Freezers	0.0050
Compact Upright Freezers with Manual Defrost	0.0075
Compact Upright Freezers with Automatic Defrost	0.0103
Compact Chest Freezers	0.0064

If configuration is unknown assume 0.0067 kW.

Annual Fossil Fuel Savings Algorithm

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.

⁶⁷ 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).



n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV time of sale incremental cost for this measure is \$12.14 for an upright freezer and \$6.62 for a chest freezer⁶⁸.

Measure Life

The measure life is assumed to be 12 years⁶⁹.

Operation and Maintenance Impacts

n/a

⁶⁸ 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>

⁶⁹ Energy Star Freezer Calculator;

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?a8fb-c882&a8fb-c882



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 $\geq 10\%$, $\geq 15\%$ or $\geq 20\%$ less energy consumption than an equivalent unit meeting federal standard requirements respectively). The algorithms for calculating Federal Baseline consumption are provided below.⁷⁰ 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 ⁷¹
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	$8.54AV + 432.8$

⁷⁰ Maximum consumption for ENERGY STAR, CEE Tier 2, and CEE Tier 3 can be calculated by multiplying the federal requirements by 90%, 85%, and 80%, respectively.

⁷¹ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43



Definition of Baseline Condition

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

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

Where:

kWh_{BASE} = 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:

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

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8⁷²:

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	368.8	331.9	313.5	295.0	36.9	55.3	73.8	0.27

⁷² Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft³ fresh volume and 6.76 ft³ freezer volume.



Refrigerator-freezers with manual defrost								
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 unknown⁷³ 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
= 1.23⁷⁴

⁷³ 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.

⁷⁴ 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



LSAF = Load Shape Adjustment Factor
= 1.15⁷⁵

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

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.

⁷⁵ 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).



Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is shown below. If configuration is unknown, assume an incremental cost of \$10 for Energy Star, \$33 for CEE Tier 2 and \$44 for CEE Tier 3.⁷⁶

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.⁷⁷

⁷⁶ 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.



Operation and Maintenance Impacts

n/a

⁷⁷ 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:

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 years⁷⁸)

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

Remaining measure life (next 8 years)

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

⁷⁸ Assumed to be 1/3 of the measure life.



Where:

kWh_{EXIST} = Annual energy consumption of existing unit
= 1146⁷⁹

kWh_{BASE} = Annual energy consumption of new baseline unit
= 511.7⁸⁰

kWh_{EE} = Annual energy consumption of ENERGY STAR unit
= 460.8⁸¹

Or = Annual energy consumption of CEE Tier 2 unit
= 435.2⁸²

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 ⁸³
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

⁷⁹ Based on EmPower 2011 Interim Evaluation Report Chapter 5: Lighting and Appliances, Table 15, p33. This suggests an average UEC of 1,146kWh.

⁸⁰ 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.

⁸¹ kWh assumptions based on using the ENERGY STAR algorithms in each product class and calculating a weighted average of the different configurations.

⁸² kWh assumptions based on 15% less than baseline consumption and calculating a weighted average of the different configurations.

⁸³ 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.



Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23⁸⁴

LSAF = Load Shape Adjustment Factor
= 1.15⁸⁵

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 3.⁸⁶

⁸⁴ 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.

⁸⁵ 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).

⁸⁶ 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



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. ⁸⁷

Operation and Maintenance Impacts

n/a

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

⁸⁷ 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 refrigerator⁸⁸ 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 unit⁸⁹.

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 coefficients⁹⁰:

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

⁸⁸ 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.

⁸⁹ Note that the hypothetical nature of this measure implies a significant amount of risk and uncertainty in developing the energy and demand impact estimates.

⁹⁰ 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

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

Where:

HDD = Heating Degree Days
= dependent on location. Use actual for location or defaults below⁹¹

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 below⁹²

Location	Cooling Degree Days	CDD / 365.25
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⁹¹ 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.

⁹² Ibid.



	(65°F set point)	
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.⁹³

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

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

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

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients⁹⁴:

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	-0.03148

⁹³ Based on EmPower DRAFT EY6 Participant Survey Results: Appliance Recycling Program Report

⁹⁴ Memo from Navigant Consulting to EmPOWER Maryland utilities, Appliance Recycling Program, Regression Modeling Analysis, Evaluation Year 6, July 12, 2016..



HDD/365.25	
Interaction: Located in Unconditioned Space x CDD/365.25	0.08217

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

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

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

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

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23⁹⁵
LSAF = Load Shape Adjustment Factor
= 1.066⁹⁶

⁹⁵ 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.

⁹⁶ 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.



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

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

Refrigerator:

$$\begin{aligned}\Delta kW &= 1098/8760 * 1.23 * 1.066 \\ &= 0.164 \text{ kW}\end{aligned}$$

Freezer:

$$\begin{aligned}\Delta kW &= 715/8760 * 1.23 * 1.066 \\ &= 0.107 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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

Measure Life

The measure life is assumed to be 8 Years.⁹⁷

Operation and Maintenance Impacts

n/a

⁹⁷ 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_0510, RS_HV_TOS_FANMTR_0510

Effective Date: June 2014

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, although the savings estimations below relate only to the efficiency gains associated with an upgrade to the efficient fan motor.

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

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

Heating Season kWh Savings from efficient fan motor = 241kWh ⁹⁸

Cooling Season kWh Savings from efficient fan motor = 178kWh ⁹⁹

⁹⁸ The average heating savings from Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003, is 400kWh. An estimate for Mid-Atlantic is provided by multiplying this by the ratio of heating degree days in Baltimore MD compared to Wisconsin (4704 / 7800).

⁹⁹ The average cooling savings from Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003, is 70 to 95kWh. An estimate for Mid-Atlantic is provided by multiplying by the ratio of full load cooling hours in Baltimore compared to



Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0^{100}$$

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.¹⁰¹

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

Southern Wisconsin (1050/487). Full load hour estimates from:

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls

¹⁰⁰ 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.

¹⁰¹ 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



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

$$\Delta \text{kWh} = (\text{Hours} * \text{Btu/hour} * (1/\text{CEER}_{\text{base}} - 1/\text{CEER}_{\text{ee}}))/1000$$

Where:

Hours = Run hours of Window AC unit

= 325¹⁰²

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:

= 8500¹⁰³

CEER_{base} = Efficiency of baseline unit in Btus per Watt-hour

= Actual (see table above)

If average deemed value required use 10.9¹⁰⁴

CEER_{ee} = Efficiency of ENERGY STAR unit in Btus per Watt-hour

= Actual

If average deemed value required use 12.0¹⁰⁵ for an ENERGY STAR

unit

Using deemed values above:

ΔkWh

$$= (325 * 8500 * (1/10.9 - 1/12)) / 1000$$

$$= 23.2 \text{ kWh}$$

¹⁰² 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.

¹⁰³ Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

¹⁰⁴ Minimum Federal Standard for most common Room AC type – 8000-14,999 capacity range with louvered sides.

¹⁰⁵ Minimum qualifying for ENERGY STAR most common Room AC type – 8000-14,999 capacity range with louvered sides.



Summer Coincident Peak kW Savings Algorithm

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

Where:

CF = Summer Peak Coincidence Factor for measure

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

$$= 0.31^{106}$$

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

$$= 0.3^{107}$$

Using deemed values above:

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

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

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

¹⁰⁶ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

¹⁰⁷ 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 Cost¹⁰⁸

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

Measure Life

The measure life is assumed to be 12 years.¹⁰⁹

Operation and Maintenance Impacts

n/a

¹⁰⁸ 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

¹⁰⁹ 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_0415, RS_HV_EREP_CENA/C_0415

Effective Date: June 2015

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	11.8 ¹¹⁰
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. Most units replaced as a result of a home energy audit are considered early replacement.

The savings methodology provided is applicable only where the baseline and efficient capacities are equal.

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.

¹¹⁰ Typical EER for units with SEER of 14, from the AHRI directory



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 measure life.

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:

$$\Delta \text{kWh} = (\text{Hours} * \text{Btu/hour} * (1/\text{SEER}_{\text{base}} - 1/\text{SEER}_{\text{ee}}))/1000$$

Early replacement¹¹¹:

$$\begin{aligned} \Delta \text{kWh for remaining life of existing unit (1st 6 years):} \\ = ((\text{Hours} * \text{Btu/hour} * (1/\text{SEER}_{\text{exist}} - 1/\text{SEER}_{\text{ee}}))/1000) \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh for remaining measure life (next 12 years):} \\ = ((\text{Hours} * \text{Btu/hour} * (1/\text{SEER}_{\text{base}} - 1/\text{SEER}_{\text{ee}}))/1000) \end{aligned}$$

Where:

Hours = Full load cooling hours

Dependent on location as below:

Location	Run Hours
Wilmington, DE	524 ¹¹²

¹¹¹ 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).

¹¹² 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



<i>Baltimore, MD</i>	<i>542 ¹¹³</i>
<i>Washington, DC</i>	<i>681</i>

Btu/Hour = Size of equipment in Btu/hour (note 1 ton = 12,000Btu/hour)
= Actual installed

SEERbase = Seasonal Energy Efficiency Ratio Efficiency of baseline unit
= 14 ¹¹⁴

SEERexist = Seasonal Energy Efficiency Ratio of existing unit (kBtu/kWh)
= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11. ¹¹⁵

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 unit with SEER rating of 15, in Baltimore:

$$\Delta \text{kWh} = (542 * 36000 * (1/14 - 1/15)) / 1000$$

$$= 93 \text{ kWh}$$

Early Replacement example: a 3-ton unit with SEER rating of 15 replaces an existing unit in Baltimore:

$$\Delta \text{kWh (for first 6 years)} = (542 * 36000 * (1/11 - 1/15)) / 1000$$

$$= 473 \text{ kWh}$$

$$\Delta \text{kWh (for next 12 years)} = (542 * 36000 * (1/14 - 1/15)) / 1000$$

Baltimore MD (1,050) from the ENERGY STAR calculator.

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

¹¹³ 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.

¹¹⁴ Minimum Federal Standard.

¹¹⁵ Based on analysis of standard efficiency units by age of unit from RECS 2015 survey.



$$= 93 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

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

Early replacement:

ΔkW for remaining life of existing unit (1st 6 years):

$$= \text{Btu/hour} * (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{ee}})/1000 * \text{CF}$$

ΔkW for remaining measure life (next 12 years):

$$= \text{Btu/hour} * (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}})/1000 * \text{CF}$$

Where:

EER_{base} = Energy Efficiency Ratio Efficiency of baseline unit
= 11.8

$\text{EER}_{\text{exist}}$ = EER Efficiency of existing unit
= Actual EER of unit should be used, if EER is unknown, use 9.9¹¹⁶

EER_{ee} = 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)
= 0.69¹¹⁷

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
= 0.66¹¹⁸

¹¹⁶ 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: $(-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$. 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.

¹¹⁷ 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.

¹¹⁸ 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.



Illustrative example – do not use as default assumption

Time of Sale example: a 3-ton unit with EER rating of 12.5:

$$\begin{aligned}\Delta kW_{SSP} &= (36000 * (1/11.8 - 1/12.5)) / 1000 * 0.69 \\ &= 0.12 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= (36000 * (1/11.8 - 1/12.5)) / 1000 * 0.66 \\ &= 0.11 \text{ kW}\end{aligned}$$

Early Replacement example: a 3-ton unit with EER rating of 12.5 replaces an existing unit in Baltimore:

ΔkW for remaining life of existing unit (1st 6 years):

$$\begin{aligned}\Delta kW_{SSP} &= (36000 * (1/9.9 - 1/12.5)) / 1000 * 0.69 \\ &= 0.52 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= (36000 * (1/9.8 - 1/12.5)) / 1000 * 0.66 \\ &= 0.52 \text{ kW}\end{aligned}$$

ΔkW for remaining measure life (next 12 years):

$$\begin{aligned}\Delta kW_{SSP} &= (36000 * (1/11.8 - 1/12.5)) / 1000 * 0.69 \\ &= 0.12 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{PJM} &= (36000 * (1/11.8 - 1/12.5)) / 1000 * 0.66 \\ &= 0.11 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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



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.¹¹⁹

The lifecycle NPV incremental costs per ton for this measure are provided below:¹²⁰

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.¹²¹

Remaining life of existing equipment is assumed to be 6 years¹²².

Operation and Maintenance Impacts

n/a

Air Source Heat Pump

¹¹⁹ Contractors may be reluctant to retrofit ECM fans due to concerns about compatibility and voiding manufacturer warranties.

¹²⁰ 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

¹²¹ 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>.

¹²² Assumed to be one third of the effective useful life.



Unique Measure Code: RS_HV_TOS_ASHP_0415, RS_HV_EREP_ASHP_0415,
Effective Date: June 2015
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 ¹²³
Federal Standard as of 1/1/2015	8.2	14	11.8 ¹²⁴
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 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. Most units replaced as a result of a home energy audit are considered early replacement.

The savings methodology provided is applicable only where the baseline and efficient capacities are equal.

¹²³ HSPF, SEER and EER refer to Heating Seasonal Performance Factor, Seasonal Energy Efficiency Ratio, and Energy Efficiency Ratio, respectively

¹²⁴ The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER2) + (1.12 * SEER)$ Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.



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 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 measure life as provided below:

Existing Equipment Type	HSPF	SEER Rating	EER Rating
ASHP	8.2	14	11.8
Electric Resistance and Central AC	3.41	13	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

Time of Sale:

$$\Delta \text{kWh} = (\text{FLHcool} * \text{BtuH} * (1/\text{SEERbase} - 1/\text{SEERee}))/1,000 + (\text{FLHheat} * \text{BtuH} * (1/\text{HSPFbase} - 1/\text{HSPFee}))/1,000$$

Early replacement¹²⁵:

ΔkWh for remaining life of existing unit (1st 6 years):

¹²⁵ 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).



$$= (FLH_{cool} * BtuH_{cool} * (1/SEER_{exist} - 1/SEER_{ee}))/1,000 + (FLH_{heat} * BtuH_{heat} * (1/HSPF_{exist} - 1/HSPF_{ee}))/1,000$$

ΔkWh for remaining measure life (next 12 years):

$$= (FLH_{cool} * BtuH_{cool} * (1/SEER_{basereplace} - 1/SEER_{ee}))/1,000 + (FLH_{heat} * BtuH_{heat} * (1/HSPF_{basereplace} - 1/HSPF_{ee}))/1,000$$

Where:

FLH_{cool}

= Full Load Cooling Hours

= Dependent on location as below:

Location	FLH _{cool}
Wilmington, DE	719 ¹²⁶
Baltimore, MD	744 ¹²⁷
Washington, DC	935

BtuH_{cool}

= Cooling capacity of Air Source Heat Pump (1 ton = 12,000Btu/h)

= Actual

SEER_{base}

= Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump

= 14¹²⁸

SEER_{exist}

= Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate. If not, assume the following dependent on type of existing cooling system:

Existing Cooling System	SEER _{exist} ¹²⁹
-------------------------	--------------------------------------

¹²⁶ 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)

¹²⁷ 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.



<i>Air Source Heat Pump or Central AC</i>	<i>11</i>
<i>No central cooling¹³⁰</i>	<i>Make '1/SEERexist' = 0</i>

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

SEER_{basereplace} = *Seasonal Energy Efficiency Ratio of new baseline replacement of same equipment type as existing:*

Existing Equipment Type	SEER Rating
ASHP	14
Central AC or no replaced cooling	13

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

Location	FLH_{heat}
<i>Wilmington, DE</i>	<i>935¹³¹</i>
<i>Baltimore, MD</i>	<i>866¹³²</i>
<i>Washington, DC</i>	<i>822</i>

BtuH_{Heat} = *Heating capacity of Air Source Heat Pump (1 ton = 12,000Btuh)*
= *Actual*

¹²⁹ Estimate based on analysis of age of current Air Conditioning equipment in the Mid Atlantic census region from the Residential Energy Consumption Survey (RECS) 2015.

¹³⁰ 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.

¹³¹ 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)

¹³² 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.



HSPF_{base} = Heating Seasonal Performance Factor of baseline Air Source Heat Pump
= 8.2¹³³

HSPF_{exist} = Heating System Performance Factor¹³⁴ of existing heating system (kBtu/kWh)

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

Existing Heating System	HSPF _{exist}
Air Source Heat Pump	6.8 ¹³⁵
Electric Resistance	3.41 ¹³⁶

HSPF_{ee} = Heating Seasonal Performance Factor of efficient Air Source Heat Pump
= Actual

HSPF_{basereplace} = Heating System Performance Factor of new baseline replacement of same equipment type as existing (kBtu/kWh)

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

Illustrative example – do not use as default assumption

Time of Sale example: a 3-ton unit with a SEER rating of 15 and HSPF of 8.5 in Baltimore, MD:

$$\Delta \text{kWh} = (744 * 36,000 * (1/14 - 1/15))/1,000 + (866 * 36,000 * (1/7.7 - 1/8.5))/1,000$$

¹³³ Minimum Federal Standard

¹³⁴ 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.

¹³⁵ Federal Standard for units manufactured before 2006.

¹³⁶ Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.



$$= 509 \text{ kWh}$$

Early Replacement example: a 3-ton unit with a SEER rating of 15 and HSPF of 8.5 in Baltimore, MD is installed replacing an existing working Central AC system with a SEER rating of 12 and electric resistance heating:

$$\Delta \text{kWh (for first 6 years)} = (744 * 36,000 * (1/11 - 1/15))/1,000 + (866 * 36,000 * (1/3.41 - 1/8.5))/1,000$$

$$= 6,124 \text{ kWh}$$

$$\Delta \text{kWh (for remaining 12 years)} = (744 * 36,000 * (1/13 - 1/15))/1,000 + (866 * 36,000 * (1/3.41 - 1/8.5))/1,000$$

$$= 5,749 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta \text{kW} = \text{BtuH}_{\text{Cool}} * (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}})/1,000 * \text{CF}$$

Early replacement:

ΔkW for remaining life of existing unit (1st 6 years):

$$= \text{BtuH}_{\text{Cool}} * (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{ee}})/1000 * \text{CF}$$

ΔkW for remaining measure life (next 12 years):

$$= \text{BtuH}_{\text{Cool}} * (1/\text{EER}_{\text{basereplace}} - 1/\text{EER}_{\text{ee}})/1000 * \text{CF}$$

Where:

$$\begin{aligned} \text{EER}_{\text{base}} &= \text{Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump} \\ &= 11.8^{137} \end{aligned}$$

¹³⁷ 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: (-



EER_{exist} = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

= Use actual EER rating where it is possible to measure or reasonably estimate. If EER unknown but SEER available convert using the equation:

$$EER = (-0.02 * SEER^2) + (1.12 * SEER)^{138}$$

If SEER rating unavailable, use available, use:

Existing Cooling System	EER _{exist}
Air Source Heat Pump or Central AC	9.9
No central cooling ¹³⁹	Make '1/EER _{exist} ' = 0

EER_{ee} = Energy Efficiency Ratio (EER) of Efficient Air Source Heat Pump
= Actual
If EER is unknown, calculate based on formula presented above.

EER_{basereplace} = Energy Efficiency Ratio of new baseline replacement of same 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)
= 0.69¹⁴⁰

0.02 * SEER²) + (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).

¹³⁸ From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

¹³⁹ 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.

¹⁴⁰ 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.



$$\begin{aligned} CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Central A/C} \\ &\quad \text{(June to August weekdays between 2 pm and 6 pm) valued} \\ &\quad \text{at peak weather} \\ &= 0.66^{141} \end{aligned}$$

Illustrative example – do not use as default assumption

Time of Sale example: a 3-ton unit with EER rating of 12.5 in Baltimore, MD:

$$\begin{aligned} \Delta kW_{SSP} &= 36,000 * (1/11.8 - 1/12.5)/1,000 * 0.69 \\ &= 0.118 \text{ kW} \end{aligned}$$

Early Replacement example: a 3-ton unit with an EER rating of 12.5 in Baltimore, MD is installed replacing an existing working Central AC system with an EER rating of 9.2 and electric resistance heating:

ΔkW for remaining life of existing unit (1st 6 years):

$$\begin{aligned} \Delta kW_{SSP} &= 36,000 * (1/9.9 - 1/12.5)/1,000 * 0.69 \\ &= 0.52 \text{ kW} \end{aligned}$$

ΔkW for remaining measure life (next 12 years):

$$\begin{aligned} \Delta kW_{SSP} &= 36,000 * (1/11.8 - 1/12.5)/1,000 * 0.69 \\ &= 0.118 \text{ kW} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

¹⁴¹ 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 lifecycle NPV incremental costs per ton for this measure are provided below:¹⁴²

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 years¹⁴³.

Operation and Maintenance Impacts

n/a

¹⁴² 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

¹⁴³ 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>



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:

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

Estimate of Cooling savings from reduction in Air Conditioning Load:

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

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

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

FLH_{cool} = Full Load Cooling Hours

= Dependent on location as below:

Location	FLHcool
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<i>Location</i>	<i>FLHcool</i>
<i>Wilmington, DE</i>	<i>524¹⁴⁴</i>
<i>Baltimore, MD</i>	<i>542¹⁴⁵</i>
<i>Washington, DC</i>	<i>681</i>

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual
ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available, use¹⁴⁶:

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

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:

$DE_{\text{before}} = 0.80$
 $DE_{\text{after}} = 0.90$

Energy Savings:

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

¹⁴⁴ 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)

¹⁴⁵ 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.

¹⁴⁶ 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.



$$= 191 \text{ kWh}$$

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

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

Where:

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

Location	FLH _{heat}
Wilmington, DE	935 ¹⁴⁷
Baltimore, MD	866 ¹⁴⁸
Washington, DC	822

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)

= Actual

η_{Heat} = Efficiency in COP of Heating equipment

= actual. If not available, use¹⁴⁹:

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

¹⁴⁷ 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)

¹⁴⁸ 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.

¹⁴⁹ 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.



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

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

Energy Savings:

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

Methodology 2: Modified Blower Door Subtraction

Total Annual Savings:

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

Claiming Cooling savings from reduction in Air Conditioning Load:

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

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

Where:

- 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}¹⁵⁰ and factor in Supply and Return Loss Factors

$$\text{Duct Leakage Reduction } (\Delta\text{CFM25}_{\text{DL}}) = (\text{Pre CFM50}_{\text{DL}} - \text{Post CFM50}_{\text{DL}}) * 0.64 * (\text{SLF} + \text{RLF})$$

Where :

$$\begin{aligned} \text{SLF} &= \text{Supply Loss Factor} \\ &= \% \text{ leaks sealed located in Supply ducts} * 1^{151} \\ &\text{Default} = 0.5^{152} \\ \text{RLF} &= \text{Return Loss Factor} \\ &= \% \text{ leaks sealed located in Return ducts} * 0.5^{153} \\ &\text{Default} = 0.25^{154} \end{aligned}$$

- c. Calculate Energy Savings:

$$\Delta\text{kWh}_{\text{cooling}} = ((\Delta\text{CFM25}_{\text{DL}}) / (\text{Capacity} * 400)) * \text{FLH}_{\text{cool}} * \text{BtuH} / 1000 / \eta_{\text{Cool}}$$

Where:

$$\begin{aligned} \Delta\text{CFM25}_{\text{DL}} &= \text{Duct leakage reduction in CFM25} \\ \text{Capacity} &= \text{Capacity of Air Cooling system (tons)} \end{aligned}$$

¹⁵⁰ 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).

¹⁵¹ 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>

¹⁵² Assumes 50% of leaks are in supply ducts.

¹⁵³ 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>

¹⁵⁴ Assumes 50% of leaks are in return ducts.



400 = Conversion of Capacity to CFM (400CFM / ton)
FLHcool = Full Load Cooling Hours
 = Dependent on location as below:

<i>Location</i>	<i>FLHcool</i>
<i>Wilmington, DE</i>	<i>524¹⁵⁵</i>
<i>Baltimore, MD</i>	<i>542¹⁵⁶</i>
<i>Washington, DC</i>	<i>681</i>

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
 = Actual
ηCool = Efficiency in SEER of Air Conditioning equipment
 = actual. If not available, use¹⁵⁷:

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

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:
 CFM_{50Whole House} = 4,800 CFM₅₀

¹⁵⁵ 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)

¹⁵⁶ 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.

¹⁵⁷ 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.



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

After:

$$\begin{aligned} \text{CFM50}_{\text{Whole House}} &= 4,600 \text{ CFM50} \\ \text{CFM50}_{\text{Envelope Only}} &= 4,500 \text{ CFM50} \\ \text{House to duct pressure} &= 43 \text{ Pascals} \\ &= 1.39 \text{ SCF (Energy Conservatory look up table)} \end{aligned}$$

Duct Leakage at CFM50:

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

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

Duct Leakage reduction at CFM25:

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

Energy Savings:

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

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

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

Where:

$$\begin{aligned} \Delta \text{CFM25}_{\text{DL}} &= \text{Duct leakage reduction in CFM25} \\ \text{Capacity} &= \text{Capacity of Air Cooling system (tons)} \\ 400 &= \text{Conversion of Capacity to CFM (400CFM / ton)} \\ \text{FLHheat} &= \text{Full Load Heating Hours} \end{aligned}$$



= *Dependent on location as below:*

<i>Location</i>	<i>FLH_{heat}</i>
<i>Wilmington, DE</i>	<i>935¹⁵⁸</i>
<i>Baltimore, MD</i>	<i>866¹⁵⁹</i>
<i>Washington, DC</i>	<i>822</i>

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
 = Actual
 η_{Heat} = *Efficiency in COP of Heating equipment*
 = *actual. If not available, use¹⁶⁰:*

<i>System Type</i>	<i>Age of Equipment</i>	<i>HSPF Estimate</i>	<i>COP Estimate</i>
<i>Heat Pump</i>	<i>Before 2006</i>	<i>6.8</i>	<i>2.00</i>
	<i>2006-2014</i>	<i>7.7</i>	<i>2.26</i>
	<i>2015 on</i>	<i>8.2</i>	<i>2.40</i>
<i>Resistance</i>	<i>n/a</i>	<i>n/a</i>	<i>1.00</i>

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:

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

$$= 362 \text{ kWh}$$

¹⁵⁸ 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)

¹⁵⁹ 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.

¹⁶⁰ 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.



Methodology 3: Duct Blaster Testing

Total Annual Savings:

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

Claiming Cooling savings from reduction in Air Conditioning Load:

$$\Delta kWh_{cooling} = (((Pre_CFM25 - Post_CFM25) / (Capacity * 400)) * FLH_{cool} * BtuH) / 1000 / \eta_{Cool}$$

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:

$$Pre_CFM25 = 220 \text{ CFM25}$$

$$Post_CFM25 = 80 \text{ CFM25}$$

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

$$= 200 \text{ kWh}$$

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

$$\Delta kWh_{Heating} = (((Pre_CFM25 - Post_CFM25) / (Capacity * 400)) * FLH_{heat} * BtuH) / 1,000,000 / \eta_{Heat} * 293.1$$

Where:

All other variables as provided above.



Illustrative example – do not use as default assumption

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

$$\begin{aligned}\Delta \text{kWh}_{\text{Heating}} &= (((220 - 80) / (3 * 400)) * 866 * 36,000) / 1,000,000 / 2.5 * \\ &293.1 \\ &= 426 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh}_{\text{Cooling}} / \text{FLH}_{\text{cool}} * \text{CF}$$

Where:

$$\begin{aligned}CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)} \\ &= 0.69^{161} \\ CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather} \\ &= 0.66^{162}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

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

$$\Delta \text{MMBTU}_{\text{fossil fuel}} = (((\text{DE}_{\text{after}} - \text{DE}_{\text{before}}) / \text{DE}_{\text{after}})) * \text{FLH}_{\text{heat}} * \text{BtuH}) / 1,000,000 / \eta_{\text{Heat}}$$

Where:

$$\text{DE}_{\text{after}} = \text{Distribution Efficiency after duct sealing}$$

¹⁶¹ 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.

¹⁶² 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.



DE_{before} = Distribution Efficiency before duct sealing
 FLH_{heat} = Full Load Heating Hours
 = 620¹⁶³
 $BtuH$ = Capacity of Heating System
 = Actual
 η_{Heat} = Efficiency of Heating equipment
 = Actual¹⁶⁴. If not available, use 84%¹⁶⁵.

Illustrative example – do not use as default assumption

Duct sealing in a fossil fuel heated house with a 100,000Btuh, 80% AFUE natural gas furnace, with the following duct evaluation results:

DE_{before} = 0.80
 DE_{after} = 0.90
 Energy Savings:
 $\Delta MMBTU = ((0.90 - 0.80) / 0.90) * 620 * 100,000 / 1,000,000 / 0.80$
 = 8.6 MMBtu

Methodology 2: Modified Blower Door Subtraction

$\Delta MMBTU = (((\Delta CFM25_{DL} / (BtuH * 0.0126)) * FLH_{heat} * BtuH) / 1,000,000 / \eta_{Heat}$

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25
 $BtuH$ = Capacity of Heating System (Btuh)

¹⁶³ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

¹⁶⁴ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

¹⁶⁵ The equipment efficiency default is based on data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%.



$$\begin{aligned}
 &= \text{Actual} \\
 0.0126 &= \text{Conversion of Capacity to CFM (0.0126CFM / Btuh)}^{166} \\
 FLH_{\text{heat}} &= \text{Full Load Heating Hours} \\
 &= 620^{167} \\
 \eta_{\text{Heat}} &= \text{Efficiency of Heating equipment} \\
 &= \text{Actual}^{168}. \text{ If not available, use 84\%}^{169}.
 \end{aligned}$$

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:

$$\begin{aligned}
 \text{Energy Savings:} \\
 \Delta \text{MMBTU} &= (((119 / (100,000 * 0.0126)) * 620 * 100,000) / 1,000,000 / 0.80 \\
 &= 7.3 \text{ MMBtu}
 \end{aligned}$$

Methodology 3: Duct Blaster Testing

$$\Delta \text{MMBTU} = (((\text{Pre_CFM}_{25} - \text{Post_CFM}_{25} / (\text{BtuH} * 0.0126)) * FLH_{\text{heat}} * \text{BtuH}) / 1,000,000 / \eta_{\text{Heat}}$$

Where:

All variables as provided above

Illustrative example – do not use as default assumption

¹⁶⁶ 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.

¹⁶⁷ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

¹⁶⁸ Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

¹⁶⁹ 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%.



Duct sealing in a house with a 100,000Btuh, 80% AFUE natural gas furnace and with the duct blaster results described above:

Energy Savings:

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

$$= 8.6 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

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 years¹⁷⁰.

Operation and Maintenance Impacts

n/a

¹⁷⁰ 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_0415, RS_HV_EREP_ASHP_0415

Effective Date: June 2015

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	8.5 ¹⁷¹	8.2

Definition of Efficient Condition

¹⁷¹ Typical EER for units with a SEER of 14 from the AHRI database.



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.

Annual Energy Savings Algorithm

If displacing/replacing electric heat:

$$\begin{aligned}\Delta kWh_{total} &= \Delta kWh_{cool} + \Delta kWh_{heat} \\ \Delta kWh_{cool} &= CoolingLoadDHP * (1/SEER_{base} * (1 + \Delta DL_{impr} * DL_{cool}) \\ &\quad - 1/SEER_{ee}) \\ \Delta kWh_{heat} &= HeatLoadElectricDHP * (3.412/HSPF_{base} * (1 + \Delta DL_{impr} * DL_{heat}) \\ &\quad - 3.412/HSPF_{ee})\end{aligned}$$

If displacing/replacing gas heat:

$$\begin{aligned}\Delta kWh_{total} &= \Delta kWh_{cool} - Total_kWh_{heat} \\ \Delta kWh_{cool} &= CoolingLoadDHP * (1/SEER_{base} * (1 + \Delta DL_{impr} * DL_{cool}) \\ &\quad - 1/SEER_{ee}) \\ Total_kWh_{heat} &= (HeatLoadGasDHP * 293.1 * 3.412 / HSPF_{ee})\end{aligned}$$

Where:

CoolingLoadDHP

= Cooling load (kWh) that the DHP will now provide

= Actual

SEERbase

= Efficiency in SEER of existing Air Conditioner or baseline ductless heat pump (kBtu cooling/ kWh consumed)

Early Replacement = Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11¹⁷²

¹⁷² Based on analysis of typical age of existing equipment from the 2015 RECs survey. 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.



for Central AC or 10.7 for Room AC¹⁷³. If no cooling exists, assume 14.0.

Time of Sale / New Construction = 14.0¹⁷⁴

*SEER_{ee} = Efficiency in SEER of efficient ductless heat pump
= Actual (kBtu cooling/ kWh consumed)*

*HeatLoadElectricDHP
= Heating load (kWh) that the DHP will now provide
= Actual¹⁷⁵*

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

HSPF_{base} = 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 3.412¹⁷⁶ for resistance heat, 7.15¹⁷⁷ for ASHP.*

¹⁷³ Estimated by converting the minimum standard for Room A/Cs before 2005 (9.7) by 1.1 to adjust for SEER.

¹⁷⁴ Minimum Federal Standard

¹⁷⁵ For example with a Manual-J calculation or similar modeling.

¹⁷⁶ Assume COP of 1.0 converted to HSPF by multiplying by 3.412.

¹⁷⁷ 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.



$$\text{Time of Sale / New Construction} = 8.2^{178}$$

HSPFee = Heating Seasonal Performance Factor of ENERGY STAR ductless heat pump¹⁷⁹
= Actual

HeatLoadGasDHP = Heating load (MMBtu) that the DHP will now provide
= Actual¹⁸⁰

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%¹⁸¹.

3.412 = Converts heat pump HSPF in to COP

See example calculations at end of characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \text{BtuH}_{\text{Cool}} * (1/\text{EER}_{\text{base}} * (1 + \Delta \text{DL}_{\text{impr}} * \text{DL}_{\text{cool}}) - 1/\text{EER}_{\text{ee}}))/1,000 * \text{CF}$$

Where:

BtuH_{Cool} = Cooling capacity of ductless heat pump (1 ton = 12,000Btuh)

¹⁷⁸ Minimum Federal Standard

¹⁷⁹ 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.

¹⁸⁰ For example with a Manual-J calculation or similar modeling.

¹⁸¹ 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%.



= Actual

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

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

If unknown assume 9.9¹⁸² for Central AC or 9.7 for Room AC¹⁸³.

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 = 8.5¹⁸⁴

EE_{ree} = 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 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)
= 0.31¹⁸⁵

¹⁸² Based on converting the SEER 10 to EER using the assumption $EER \approx SEER/1.1$.

¹⁸³ 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."

¹⁸⁴ Typical EER for DMSHP units with a SEER of 14 from the AHRI database

¹⁸⁵ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.



$CF_{PJM \text{ Room AC}}$ = PJM Summer Peak Coincidence Factor for Room A/C
(June to August weekdays between 2 pm and 6 pm) valued
at peak weather
= 0.3¹⁸⁶

$CF_{SSP \text{ Central AC}}$ = Summer System Peak Coincidence Factor for Central A/C
(hour ending 5pm on hottest summer weekday)
= 0.69¹⁸⁷

$CF_{PJM \text{ Central AC}}$ = PJM Summer Peak Coincidence Factor for Central A/C
(June to August weekdays between 2 pm and 6 pm) valued
at peak weather
= 0.66¹⁸⁸

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.

$$\Delta \text{MMBtu} = \text{HeatLoadGasReplaced} / \text{AFUE}_{\text{exist}} * (1 + \Delta \text{DL}_{\text{impr}} * \text{DL}_{\text{heat}})$$

Where:

$\text{HeatLoadGasReplaced}$
= Heating load (MMBtu) that the DHP will now provide in
place of gas unit

= Actual¹⁸⁹

¹⁸⁶ 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).

¹⁸⁷ 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.

¹⁸⁸ 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.



$AFUE_{exist}$ = Efficiency of existing heating system
= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 80%¹⁹⁰ for early retirement, or 80% for replace on burnouts¹⁹¹.

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:¹⁹²

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

¹⁸⁹ For example with a Manual-J calculation or similar modeling.

¹⁹⁰ 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%.

¹⁹¹ This has been estimated assuming that the average efficiency of existing heating systems is likely to include newer more efficient systems.

¹⁹² 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



Measure Life

The measure life is assumed to be 18 years¹⁹³. If an early replacement measure results in the removal of existing operating heating or cooling equipment, it is assumed that it would have needed replacing in 6 years.

Operation and Maintenance Impacts

n/a

Illustrative examples – do not use as default assumption

Early Replacement:

A 1.5 ton, 20 SEER, 14 EER, 12 HSPF, DHP replaces 5000 kWh of existing electric resistance heat load in a home without existing cooling in Baltimore, MD. DHP is estimated to provide 2,000kWh of cooling load.

$$\Delta \text{kWh} = (\text{CoolingLoadDHP} * (1/\text{SEERbase} - 1/\text{SEERee})) + (\text{HeatLoadElectricDRP} * (3.412/\text{HSPFbase} - 3.412/\text{HSPFee}))$$

$$= (2000 * (0 - 1/20)) + (5000 * (3.412/3.412 - 3.412/12))$$

$$= 3,478 \text{ kWh}$$

$$\Delta \text{kW}_{SSP} = \text{BtuH}_{\text{Cool}} * (1/\text{EERbase} - 1/\text{EERee}) / 1,000 * \text{CF}$$

$$= (18,000 * (0 - 1/14)) / 1000 * 0.31$$

$$= - 0.40 \text{ kW}$$

¹⁹³ 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>.



A 2.5 ton, 18 SEER, 13.5 EER, 11 HSPF, DHP displaces all of existing gas heat (78% AFUE) in a home with central cooling in Baltimore, MD. The heating load is estimated as 40 MMBtu and cooling load of 4000 kWh.

$$\begin{aligned}\Delta \text{kWh} &= (\text{CoolingLoadDHP} * (1/\text{SEERbase} - 1/\text{SEERee})) - \\ &\quad (\text{HeatLoadGasDHP} * 293.1 * 0.85 * (3.412/\text{HSPFee})) \\ &= (4000 * (1/11 - 1/18)) - (40 * 293.3 * 0.85 * (3.412/11)) \\ &= -2,952 \text{ kWh (i.e. this results in an increase in electric consumption)}\end{aligned}$$

$$\begin{aligned}\Delta \text{kW}_{SSP} &= \text{BtuH}_{\text{Cool}} * (1/\text{EERbase} - 1/\text{EERee}) / 1,000 * \text{CF} \\ &= (30,000 * (1/9.96 - 1/13.5)) / 1000 * 0.31 \\ &= 0.24 \text{ kW (in the summer you see demand savings)}\end{aligned}$$

$$\begin{aligned}\Delta \text{MMBtu} &= \text{HeatLoadGasReplaced} / \text{AFUEexist} \\ &= 40 / 0.80 \\ &= 50 \text{ MMBtu}\end{aligned}$$

Time of Sale / New Construction

Two 1.5 ton, 18 SEER, 13.5 EER, 11 HSPF, DHP is installed in a new home in Baltimore, MD. The estimated heat load is 12,000kWh and the cooling load is 6,000kWh

$$\begin{aligned}\Delta \text{kWh} &= (\text{CoolingLoadDHP} * (1/\text{SEERbase} - 1/\text{SEERee})) + \\ &\quad (\text{HeatLoadElectricDHP} * (3.412/\text{HSPFbase} - 3.412/\text{HSPFee})) \\ &= (6000 * (1/14 - 1/18)) + (12,000 * (3.412/7.7 - 3.412/11)) \\ &= 1,634 \text{ kWh}\end{aligned}$$

$$\Delta \text{kW}_{SSP} = \text{BtuH}_{\text{Cool}} * (1/\text{EERbase} - 1/\text{EERee}) / 1,000 * \text{CF}$$



$$= (36,000 * (1/11.8 - 1/13.5)) / 1000) * 0.31$$

$$= 0.12 \text{ kW}$$

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 \geq 90%.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBtu} = (\text{EFLHheat} * \text{Btuh} * ((\text{AFUEee}/\text{AFUEbase}) - 1)) / 1,000,000$$



Where:

EFLH_{heat} = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ¹⁹⁴
Baltimore, MD	620 ¹⁹⁵
Washington, DC	528 ¹⁹⁶

BtuH = Input Capacity of Boiler
= Actual

AFUE_{base} = Efficiency in AFUE of baseline boiler
= 82%

AFUE_{ee} = 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:

$$\begin{aligned}\Delta\text{MMBtu} &= (620 * 100,000 * ((0.9/0.82) - 1)) / 1,000,000 \\ &= 6.0 \text{ MMBtu}\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental costs for this measure are provided below:¹⁹⁷

¹⁹⁴ 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

¹⁹⁵ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

¹⁹⁶ 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.

¹⁹⁷ 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>



Efficiency of Boiler (AFUE)	Incremental Cost
90%	\$469
92%	\$513
95%	\$643
98%	\$789

Measure Life

The measure life is assumed to be 18 years¹⁹⁸.

Operation and Maintenance Impacts

n/a

¹⁹⁸ 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 weatherized¹⁹⁹.

Definition of Efficient Condition

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

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

$$\Delta \text{MMBtu} = (\text{EFLHheat} * \text{Btuh} * ((\text{AFUEee}/\text{AFUEbase}) - 1) / 1,000,000$$

¹⁹⁹ Current federal minimum. See <http://www.regulations.gov/#!documentDetail;D=EERE-2006-STD-0102-0008>.



Where:

EFLH_{heat} = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ²⁰⁰
Baltimore, MD	620 ²⁰¹
Washington, DC	528 ²⁰²

BtuH = Input Capacity of Furnace
= Actual

AFUE_{base} = Efficiency in AFUE of baseline Furnace
= 0.80

AFUE_{ee} = Efficiency in AFUE of efficient Furnace
= Actual

Illustrative example – do not use as default assumption

The purchase and installation of a 100,000 Btu/h, 92% AFUE furnace in Maryland:

$$\begin{aligned}\Delta\text{MMBtu} &= (620 * 100,000 * ((0.92/0.8) - 1) / 1,000,000 \\ &= 9.3 \text{ MMBtu}\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided below.²⁰³

²⁰⁰ 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

²⁰¹ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

²⁰² 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.



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

Measure Life

The measure life is assumed to be 18 years²⁰⁴.

Operation and Maintenance Impacts

n/a

²⁰³ 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.

²⁰⁴ 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_0517, RS_HV_RF_SMTHRM_0517

Effective Date: June 2017

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 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 the in situ manually operated or properly programmed thermostat that was replaced, or an assumed (defaulted) mix of these two.

Definition of Efficient Condition

The efficient condition is a smart thermostat that has earned ENERGY STAR certification²⁰⁵ and/or has the following product requirements²⁰⁶:

1. Automatic scheduling
2. Occupancy sensing (set “on” as a default)
3. For homes with a heat pump, smart thermostats must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.
4. Ability to adjust settings remotely via a smart phone or online the absence of connectivity to the connected thermostat (CT) service provider, retain the ability for residents to locally:
 - a. view the room temperature,
 - b. view and adjust the set temperature, and
 - c. switch between off, heating and cooling.
5. Have a static temperature accuracy $\leq \pm 2.0$ °F

²⁰⁵ ENERGY STAR’s qualified products list for smart thermostats:

<https://data.energystar.gov/dataset/ENERGY-STAR-Certified-Connected-Thermostats/7p2p-wkbf>

²⁰⁶ 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



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.²⁰⁷ 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.

$$\begin{aligned}\Delta \text{kWh} &= \Delta \text{kWh}_{\text{heating}} + \Delta \text{kWh}_{\text{cooling}} \\ \Delta \text{kWh}_{\text{heating}} &= \text{Elec_Heating_Saving_}\% * \text{Elec_Heating_kWh} \\ \Delta \text{kWh}_{\text{cool}} &= \text{Cooling_Saving_}\% * \text{Cooling_kWh} \\ \Delta \text{MMBtu} &= \text{Fuel_Heating_Saving_}\% * \text{Fuel_Heating_MMBTU}\end{aligned}$$

Where:

$$\begin{aligned}\text{Elec_Heating_Saving_}\% &= 6\% \\ \text{Cooling_Saving_}\% &= 7\% \\ \text{Fuel_Heating_Saving_}\% &= 6\%.\end{aligned}$$

²⁰⁷ 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.

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.

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 (therms)	309	620	NA	522	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 (therms)	423	848	NA	714	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 (therms)	264	528	NA	445	NA

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 \$154²⁰⁸ and the incremental cost for a retrofit replacement is assumed to be \$208.²⁰⁹ If thermostats are professionally installed, \$50 for labor should be added to the assumed incremental cost.

²⁰⁸ 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.

²⁰⁹ 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



Measure Life

The measure life is assumed to be 7.5 years.²¹⁰

Operation and Maintenance Impacts

n/a

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.

²¹⁰ 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 CEER²¹¹).

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 12.0²¹²).

Annual Energy Savings Algorithm

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

$$\Delta \text{kWh} = (\text{Hours} * \text{BtuH} * (1/\text{EER}_{\text{exist}} - 1/\text{CEER}_{\text{ee}}))/1,000$$

Savings for remaining measure life (next 9 years)

$$\Delta \text{kWh} = (\text{Hours} * \text{BtuH} * (1/\text{CEER}_{\text{base}} - 1/\text{CEER}_{\text{ee}}))/1,000$$

²¹¹ Minimum Federal Standard for most common Room AC type – 8000-14,999 capacity range with louvered sides.

²¹² Minimum qualifying for ENERGY STAR most common Room AC type – 8000-14,999 capacity range with louvered sides.



Where:

<i>Hours</i>	<i>= Run hours of Window AC unit</i> <i>= 325²¹³</i>
<i>Btuh</i>	<i>= Capacity of replaced unit</i> <i>= Actual or 8,500 if unknown²¹⁴</i>
<i>EERexist</i>	<i>= Efficiency of existing unit in Btus per Watt-hour</i> <i>= 9.8²¹⁵</i>
<i>CEERbase</i>	<i>= Efficiency of baseline unit in Btus per Watt-hour</i> <i>= 10.9²¹⁶</i>
<i>CEERee</i>	<i>= Efficiency of ENERGY STAR unit in Btus per Watt-hour</i> <i>= Actual or CEER 12 if unknown</i>

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:

$$\begin{aligned}\text{Savings for remaining life of existing unit (1st 3 years)} \\ \Delta\text{kWh} &= (325 * 8,500 * (1/9.8 - 1/12)) / 1,000 \\ &= 52 \text{ kWh}\end{aligned}$$

$$\begin{aligned}\text{Savings for remaining measure life (next 9 years)} \\ \Delta\text{kWh} &= (325 * 8,500 * (1/10.9 - 1/12)) / 1,000 \\ &= 23 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

²¹³ 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.

²¹⁴ Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

²¹⁵ 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.

²¹⁶ Minimum Federal Standard for capacity range.



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

$$\Delta kW = ((BtuH * (1/EER_{exist} - 1/CEER_{ee}))/1000) * CF$$

Savings for remaining measure life (next 9 years)

$$\Delta kW = ((BtuH * (1/CEER_{base} - 1/CEER_{ee}))/1000) * CF$$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)
= 0.31²¹⁷

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
= 0.3²¹⁸

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)

$$\begin{aligned}\Delta kW_{SSP} &= ((8,500 * (1/9.8 - 1/12)) / 1,000) * 0.31 \\ &= 0.0493 \text{ kW}\end{aligned}$$

Savings for remaining measure life (next 9 years)

$$\begin{aligned}\Delta kW_{SSP} &= ((8,500 * (1/10.9 - 1/12)) / 1,000) * 0.31 \\ &= 0.0222 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

²¹⁷ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

²¹⁸ 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).



n/a

Incremental Cost

The lifecycle NPV incremental cost for this early replacement measure is provided below.²¹⁹

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 years²²⁰. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced²²¹.

Operation and Maintenance Impacts

²¹⁹ 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

²²⁰ 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>.

²²¹ Based on Connecticut TRM; Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year



The net present value of the deferred replacement cost (the cost associated with the replacement of the existing unit with a standard unit that would have occurred in 3 years, had the existing unit not been replaced) should be calculated as:

$$\text{NPV}_{\text{deferred replacement cost}} = (\text{Actual Cost of ENERGY STAR unit} - \$240^{222}) * 86\%^{223}.$$

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

²²² Itron Incremental Cost Review 2017

²²³ 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

$$\Delta \text{kWh} = ((\text{Hours} * \text{BtuH} * (1/\text{EER}_{\text{exist}}))/1,000) - (\% \text{replaced} * ((\text{Hours} * \text{BtuH} * (1/\text{EER}_{\text{newbase}}))/1,000))$$

Where:

Hours = Run hours of Window AC unit
= 325²²⁴
Btu/hour = Capacity of replaced unit
= Actual or 8,500 if unknown²²⁵

²²⁴ 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.



EER_{exist} = Efficiency of existing unit in Btus per Watt-hour
= Actual or 9.8 if unknown ²²⁶

%replaced = Percentage of units dropped off that are replaced in the home
= 76% ²²⁷

CEER_{newbase} = Efficiency of new baseline unit in Btus per Watt-hour
= 10.9 ²²⁸

Illustrative example – do not use as default assumption

The turn in of an 8,500 Btuh, 7.7 EER unit:

$$\begin{aligned}\Delta \text{kWh} &= ((325 * 8,500 * (1/9.8))/1,000) - \\ &\quad (0.76 * ((325 * 8,500 * (1/10.9))/1,000)) \\ &= 89 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = [(\text{BtuH} * (1/\text{EER}_{\text{exist}}))/1,000) - (\% \text{replaced} * \text{BtuH} * (1/\text{CEER}_{\text{newbase}}))/1,000)] * \text{CF}$$

Where:

CF_{SSP} = Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)
= 0.31 ²²⁹

²²⁵ Based on maximum capacity average from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008.

²²⁶

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.

²²⁷ 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.

²²⁸ 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.

²²⁹ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.



$$\begin{aligned} CF_{PJM} &= PJM \text{ Summer Peak Coincidence Factor for Room A/C (June to} \\ &\text{August weekdays between 2 pm and 6 pm) valued at peak} \\ &\text{weather} \\ &= 0.3^{230} \end{aligned}$$

Illustrative example – do not use as default assumption

The turn in of an 8500 Btuh, 9.8 EER unit:

$$\begin{aligned} \Delta kW_{SSP} &= ((8,500 * (1/9.8))/1,000) * 0.31 - \\ &\quad (0.76 * ((8,500 * (1/10.9))/1,000)) * 0.31 \\ &= 0.09 \text{ kW} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this measure should be the actual implementation cost for recycling the existing unit, plus \$184 to account for the replacement of 76% of the units.²³¹

Measure Life

The measure life is assumed to be 3 years²³².

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

²³⁰ 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).

²³¹ 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.

²³² 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 \$158²³³.

²³³ 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

$$\Delta \text{MMBtu} = \left(\left(\frac{1}{R_{\text{exist}}} \right) - \left(\frac{1}{R_{\text{new}}} \right) \right) * \text{FLH_heat} * C_{\text{exist}} * L * \Delta T / \eta_{\text{Boiler}} / 1,000,000$$

Where:

$$R_{\text{exist}} = \text{Pipe heat loss coefficient of uninsulated pipe } [(hr \cdot ^\circ F \cdot ft^2) / Btu] \\ = 0.5^{234}$$

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

²³⁴ 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	848 ²³⁵
Baltimore, MD	620 ²³⁶
Washington, DC	528 ²³⁷

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

C_{exist} = Circumference of bare pipe (ft) (Diameter (in) * $\pi/12$)
= Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)

ΔT = Average temperature difference between circulated heated water and unconditioned space air temperature (°F)²³⁸

Pipes location	Outdoor Reset Controls	ΔT (°F)
Unconditioned basement	Boiler without reset control	110
	Boiler with reset control	70
Crawlspace	Boiler without reset control	120
	Boiler with reset control	80

η_{Boiler} = Efficiency of boiler
= 0.84²³⁹

²³⁵ 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

²³⁶ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

²³⁷ 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.

²³⁸ 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).

²³⁹ 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:

$$\begin{aligned}\Delta \text{MMBtu} &= (((1/R_{\text{exist}}) - (1/R_{\text{new}})) * \text{FLH}_{\text{heat}} * C_{\text{exist}} * L * \Delta T) / \eta_{\text{Boiler}} \\ &\quad / 1,000,000 \\ &= (((1/0.5) - (1/3.5)) * 848 * 0.196 * 15 * 120) / 0.85 / 1,000,000 \\ &= 0.63 \text{ MMBtu}\end{aligned}$$

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.²⁴⁰

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 15 years²⁴¹.

Operation and Maintenance Impacts

N/A

²⁴⁰ Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

²⁴¹ 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

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



Where:

Savings % = Estimated percent reduction in heating load due to boiler reset controls being installed
= 5%²⁴²

EFLH_{heat} = Equivalent Full Load Heating Hours

Location	EFLH
Wilmington, DE	848 ²⁴³
Baltimore, MD	620 ²⁴⁴
Washington, DC	528 ²⁴⁵

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.

$$\begin{aligned}\Delta\text{MMBtu} &= 0.05 * (620 * 80,000)/1,000,000 \\ &= 2.48 \text{ MMBtu}\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The cost of this measure is \$612²⁴⁶

²⁴² 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/>

²⁴³ 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

²⁴⁴ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

²⁴⁵ 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.

²⁴⁶ Nexant. Questar DSM Market Characterization Report. August 9, 2006.



Measure Life

The life of this measure is 15 years²⁴⁷

Operation and Maintenance Impacts

n/a

²⁴⁷ New York State TRM v4.0, April 2016



Ground Source Heat Pumps

Unique Measure Code: RS_HV_TOS_GSHPS_0415, RS_HV_NC_GSHPS_0415

Effective Date: June 2015

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 ²⁴⁸	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. 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

²⁴⁸ 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.



New Construction:

The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8²⁴⁹ 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 follows²⁵⁰:

$$\begin{array}{lll} \text{For } \leq 55 \text{ gallons:} & \text{EF} & = 0.96 - (0.0003 * \text{rated volume in gallons}) \\ \text{For } > 55 \text{ gallons:} & \text{EF} & = 2.057 - (0.00113 * \text{rated volume in gallons}) \end{array}$$

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:

$$\text{EF} = 0.93 - (0.00132 * \text{rated volume in gallons})^{251}$$

If size is unknown, assume 50 gallon; 0.864 EF

If gas water heater, and unknown efficiency – assume efficiency is equal to pre 4/2015 Federal Standard:

$$\text{EF} = (0.67 - 0.0019 * \text{rated volume in gallons})^{252}.$$

If size is unknown, assume 40 gallon; 0.594 EF

²⁴⁹ The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * \text{SEER}^2) + (1.12 * \text{SEER})$ Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

²⁵⁰ 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>

²⁵¹ 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

²⁵² 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



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

Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment must be a Ground Source Heat Pump unit meeting the minimum ENERGY STAR efficiency level standards effective at the time of installation as detailed above.

Annual Energy Savings Algorithm

$$\begin{aligned} \Delta \text{kWh} &= [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \\ &= [(\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}})/1000)] + \\ &\quad [\text{FLHheat} * \text{Capacity_heating} * (1/\text{HSPF}_{\text{base}} - (1/(\text{COP}_{\text{PL}} * 3.412)))/1000] + \\ &\quad [\text{ElecDHW} * \% \text{DHWD} \text{Displaced} * (((1/\text{EF}_{\text{ELEC}}) * \text{GPD} * \text{Household} * 365.25 * \\ &\quad \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)] \end{aligned}$$

Where:

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

Location	Run Hours
Wilmington, DE	524 ²⁵³
Baltimore, MD	542 ²⁵⁴
Washington, DC	681

Capacity_cooling = Cooling Capacity of Ground Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

SEERbase = SEER Efficiency of new replacement baseline unit
= 14²⁵⁵

²⁵³ 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)

²⁵⁴ 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.



EER_{PL} = Part Load EER Efficiency of efficient GSHP unit²⁵⁶
= Actual installed

FLH_{heat} = Full load heating hours

Location	EFLH
Wilmington, DE	848 ²⁵⁷
Baltimore, MD	620 ²⁵⁸
Washington, DC	528 ²⁵⁹

$Capacity_{heating}$ = Heating Capacity of Ground Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

$HSPF_{base}$ = Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)
= 8.2²⁶⁰

COP_{PL} = Part Load Coefficient of Performance of efficient unit²⁶¹
= Actual Installed

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

²⁵⁵ 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>

²⁵⁶ As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

²⁵⁷ 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

²⁵⁸ Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program, technical report", June 1995. For other utilities offering this measure, a Heating Degree Day adjustment may be appropriate to this FLH_{heat} assumption.

²⁵⁹ 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.

²⁶⁰ 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>

²⁶¹ As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.



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%²⁶²
= 0% if no desuperheater installed

EF_{ELEC} = Energy Factor (efficiency) of electric water heater

For new construction assume federal standard²⁶³:

For ≤55 gallons: $0.96 - (0.0003 * \text{rated volume in gallons})$

For >55 gallons: $2.057 - (0.00113 * \text{rated volume in gallons})$

If size is unknown, assume 50 gallon; 0.945 EF.

For Time of Sale, if electric DHW use Actual efficiency. If unknown
– assume efficiency is equal to pre 4/2015 Federal Standard:

$EF = 0.93 - (0.00132 * \text{rated volume in gallons})$ ²⁶⁴

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 household²⁶⁵
= 17.6

Household = Average number of people per household

²⁶² 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.

²⁶³ 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>

²⁶⁴ Federal Standard from 2004 until 2015, Federal Register Vol. 66, No. 11/1/17/2001, page 4497,
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_f_r.pdf

²⁶⁵ Based upon email message from Maureen Hodgins, Research Manager for Water Research Foundation, on August 26, 2014.



$$= 2.53^{266}$$

$$365.25 = \text{Days per year}$$

$$\gamma_{\text{Water}} = \text{Specific weight of water} \\ = 8.33 \text{ pounds per gallon}$$

$$T_{\text{OUT}} = \text{Tank temperature} \\ = 125^{\circ}\text{F}$$

$$T_{\text{IN}} = \text{Incoming water temperature from well or municipal system} \\ = 60.9^{267}$$

$$1.0 = \text{Heat Capacity of water (1 Btu/lb}^{\circ}\text{F)}$$

$$3412 = \text{Conversion from Btu to kWh}$$

Illustrative Example – do not use as default assumption

New Construction:

For example, a 3-ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed with a 50-gallon electric water heater in single family house in Baltimore:

$$\Delta \text{kWh} = [(\text{FLHcool} * \text{Capacity_cooling} * (1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}}))/1000] + [(\text{FLHheat} \\ * \text{Capacity_heating} * (1/\text{HSPF}_{\text{base}} - (1/\text{COP}_{\text{PL}} * 3.412)))/1000] + \\ [\text{ElecDHW} * \% \text{DHWDisplaced} * (((1/\text{EF}_{\text{ELEC EXIST}}) * \text{GPD} * \text{Household} * \\ 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)]$$

$$\Delta \text{kWh} = [(542 * 36,000 * (1/14 - 1/19)) / 1000] + [(620 * 36,000 * (1/8.2 - 1/ \\ (4.4 * 3.412))) / 1000] + [1 * 0.44 * (((1/0.945) * 17.6 * 2.53 * 365.25 * 8.33 \\ * (125 - 60.9) * 1) / 3412)]$$

²⁶⁶ 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>

²⁶⁷ 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.



$$= 367 + 1235 + 1185$$

$$= 2787 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\text{Capacity_cooling} * (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{FL}}))/1000) * CF$$

Where:

EER_{base} = EER Efficiency of new replacement unit
= 11.8²⁶⁸

EER_{FL} = Full Load EER Efficiency of ENERGY STAR GSHP unit²⁶⁹
= Actual

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69²⁷⁰

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
= 0.66²⁷¹

Illustrative Example— do not use as default assumption

New Construction or Time of Sale:

For example, a 3-ton unit with Full Load EER rating of 19:

$$\begin{aligned}\Delta kW_{\text{SSP}} &= ((36,000 * (1/11.8 - 1/19))/1000) * 0.69 \\ &= 0.80 \text{ kW}\end{aligned}$$

²⁶⁸ The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.

²⁶⁹ 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.

²⁷⁰ 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.

²⁷¹ 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.



$$\begin{aligned}\Delta kW_{PJM} &= ((36,000 * (1/11 - 1/19))/1000) * 0.66 \\ &= 0.76 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

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

$$\begin{aligned}\Delta \text{MMBtu} &= [\text{DHW Savings}] \\ &= [(1 - \text{ElecDHW}) * \% \text{DHWDisplaced} * (1/ \text{EF}_{\text{GAS BASE}} * \text{GPD} * \\ &\quad \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 1,000,000]\end{aligned}$$

Where:

$$\begin{aligned}\text{EF}_{\text{GAS EXIST}} &= \text{Energy Factor (efficiency) of existing gas water heater} \\ &= \text{Actual. If unknown assume efficiency is equal to pre 4/2015} \\ &\quad \text{Federal Standard:} \\ &= (0.67 - 0.0019 * \text{rated volume in gallons})^{272}.\end{aligned}$$

If size is unknown, assume 40 gallons; 0.594 EF

All other variables provided above

Illustrative Example – do not use as default assumption

Time of Sale:

For example, a GSHP with desuperheater is installed with a 40-gallon gas water heater in single family house in Baltimore:

$$\begin{aligned}\Delta \text{MMBtu} &= [(1 - \text{ElecDHW}) * \% \text{DHWDisplaced} * (1/ \text{EF}_{\text{GAS BASE}} * \text{GPD} * \\ &\quad \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 1,000,000] \\ &= [(1 - 0) * 0.44 * (((1/0.594) * 17.6 * 2.53 * 365.25 * 8.33 * (125 - \\ &\quad 60.9) * 1)/1,000,000)] \\ &= 6.4 \text{ MMBtu}\end{aligned}$$

²⁷² 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



Annual Water Savings Algorithm

n/a

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 ton²⁷³), minus the assumed installed cost of the baseline equipment (\$838 per ton for ASHP²⁷⁴).

Measure Life

The expected measure life is assumed to be 20 years²⁷⁵.

Operation and Maintenance Impacts

N/A

²⁷³ Based on data provided to VEIC in 'Results of Home geothermal and air source heat pump rebate incentives documented by Illinois electric cooperatives'.

²⁷⁴ 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.

²⁷⁵ 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 3.1²⁷⁶) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2²⁷⁷.

Definition of Efficient Condition

New efficient (average CFM/watt of 8.3²⁷⁸) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate (20 CFM) indicated by ASHRAE 62.2²⁷⁹

Annual Energy Savings Algorithm

$$\Delta kWh = (CFM * (1/\eta_{Baseline} - 1/\eta_{Efficient})/1000) * \text{Hours}$$

Where:

CFM = Nominal Capacity of the exhaust fan

²⁷⁶ 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.

²⁷⁷ On/off cycling controls may be required of baseline fans larger than 50CFM.

²⁷⁸ 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.

²⁷⁹ Bi-level controls may be used by efficient fans larger than 50 CFM



$$\begin{aligned}
 \eta_{Baseline} &= 20 \text{ CFM}^{280} \\
 &= \text{Average efficacy for baseline fan} \\
 &= 3.1 \text{ CFM/Watt}^{281} \\
 \eta_{Efficient} &= \text{Average efficacy for efficient fan} \\
 &= 8.3 \text{ CFM/Watt}^{282} \\
 \text{Hours} &= \text{assumed annual run hours,} \\
 &= 8760 \text{ for continuous ventilation.}
 \end{aligned}$$

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

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = (\text{CFM} * (1/\eta_{Baseline} - 1/\eta_{Efficient})/1000) * \text{CF}$$

Where:

$$\begin{aligned}
 \text{CF} &= \text{Summer Peak Coincidence Factor} \\
 &= 1.0 \text{ (continuous operation)}
 \end{aligned}$$

Other variables as defined above

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

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

²⁸⁰ 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.

²⁸¹ 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.

²⁸² 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.



Incremental Cost

For this time of sale measure, the incremental cost per installed fan is \$43.50²⁸³.

Measure Life

The expected measure life is assumed to be 19 years²⁸⁴.

Operation and Maintenance Impacts

N/A

²⁸³ VEIC analysis using cost data collected from wholesale vendor; <http://www.westsidewholesale.com/>.

²⁸⁴ 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 designs²⁸⁵.

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)

Where²⁸⁶:

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

%Low_{ES} = Percent of time spent at Low speed of ENERGY STAR
= 40%

WattsLow_{ES} = Fan wattage at Low speed of ENERGY STAR
= Actual. If unknown use 6 watts

%Med_{ES} = Percent of time spent at Medium speed of ENERGY STAR
= 40%

WattsMed_{ES} = Fan wattage at Medium speed of ENERGY STAR
= Actual. If unknown use 23 watts



$\%High_{ES}$ = Percent of time spent at High speed of ENERGY STAR
= 20%

$WattsHigh_{ES}$ = Fan wattage at High speed of ENERGY STAR
= Actual. If unknown use 56 watts

For ease of reference, the fan assumptions are provided below in table form:

	Low Speed	Medium Speed	High Speed
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

$WattsBase$ = $3 \times 43 = 129 \text{ W}$

$WattsEE$ = $1 \times 42 = 42 \text{ W}$

Deemed savings if using defaults provided above:

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

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

ΔkWh = $11.2 + 77.3$
 = 88.5 kWh

Summer Coincident Peak kW Savings Algorithm

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

ΔkW_{Fan} = $((WattsHigh_{base} - WattsHigh_{ES}) / 1000) \times CF_{fan}$

ΔkW_{Light} = $((WattsBase - WattsEE) / 1000) \times ISR \times WHFd \times CF_{light}$

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



Where:

$CF_{fan_{SSP}}$ = Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)
= 0.31²⁸⁷

$CF_{fan_{PJM}}$ = PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.3²⁸⁸

CF_{light} = Summer Peak coincidence factor for lighting savings

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082 ²⁸⁹
	PJM CF	0.084 ²⁹⁰

Deemed savings if using defaults provided above:

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

$$= 0.0034 \text{ kW}$$

$$\Delta kW_{light_{ssp}} = ((129 - 42)/1000) * 1.0 * 1.17 * 0.082$$

$$= 0.0083 \text{ kW}$$

$$\Delta kW_{ssp} = 0.0034 + 0.0083$$

$$= 0.012 \text{ kW}$$

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

$$= 0.0033 \text{ kW}$$

$$\Delta kW_{light_{pjm}} = ((129 - 42)/1000) * 1.0 * 1.18 * 0.084$$

$$= 0.0086 \text{ kW}$$

~~-Assuming that the CF for a ceiling fan is the same as Room AC; Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.~~

~~/National%20Grid/117_RLW_CF%20Res%20RAC.pdf).~~

~~-Based on EmPOWER_EY5 Deemed Savings Recommendations_20Jan2015 DRAFT.~~

~~-Ibid.~~



$$\begin{aligned}\Delta kW_{pjm} &= 0.0033 + 0.0086 \\ &= 0.012 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

Heating penalty from improved lighting:

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

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

Deemed savings if using defaults provided above:

$$\begin{aligned}\Delta \text{MMBtuPenalty} &= - \left(\frac{(((129 - 42) / 1000) * 1.0 * 898 * 0.47 * 0.003412)}{0.84} \right) * 0.625 \\ &= -0.09\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

For this time of sale measure, the Incremental cost per unit is assumed to be \$46.²⁹¹

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_0414, RS_WT_TOS_SHWRHD_0414

Effective Date: June 2014

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:

$$\Delta \text{kWh}^{292} = (((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \# \text{ people} * \text{gals/day/person} * \text{days/year}) / \text{SH/home} * 8.3 * (\text{TEMP}_{\text{sh}} - \text{TEMP}_{\text{in}}) / 1,000,000) / \text{DHW Recovery Efficiency} / 0.003412$$

Where:

GPM_{base} = Gallons Per Minute of baseline showerhead
= 2.5²⁹³ or actual flow rate if recorded
 GPM_{low} = Gallons Per Minute of low flow showerhead

²⁹² Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all showerhead installations.

²⁹³ The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).



	<i>= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.</i>
<i># people</i>	<i>= Average number of people per household</i> <i>= 2.53²⁹⁴</i>
<i>gals/day/person</i>	<i>= Average gallons per day used for showering</i> <i>= Time_{Shower} * GPM_{Base} * Showers_{Person}</i> <i>= if unknown, use 11.6²⁹⁵</i>
<i>days/y</i>	<i>= Days shower used per year</i> <i>= 365</i>
<i>Showers/home</i>	<i>= Average number of showers in the home</i> <i>= 1.6²⁹⁶</i>
<i>8.3</i>	<i>= Constant to convert gallons to lbs</i>
<i>TEMPsh</i>	<i>= Assumed temperature of water used for shower</i> <i>= 105</i>
<i>TEMPin</i>	<i>= Assumed temperature of water entering house</i> <i>= 60.9²⁹⁷</i>
<i>DHW Recovery Efficiency</i>	<i>= Recovery efficiency of electric water heater</i> <i>= 0.98²⁹⁸</i>
<i>0.003412</i>	<i>= Constant to convert MMBtu to kWh</i>

Illustrative example – do not use as default assumption

For a 2.0GPM rated showerhead:

²⁹⁴ US Energy Information Administration, Residential Energy Consumption Survey;
http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

²⁹⁵ Most commonly quoted value of gallons of water used per person per day (including in U.S. Environmental Protection Agency's "water sense" documents; <https://www.epa.gov/watersense>)

²⁹⁶ Estimate based on review of a number of studies:

a. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications"

<http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?purl=/10185385-CEkZMk/native/>

b. East Bay Municipal Utility District; "Water Conservation Market Penetration Study"

https://www.ebmud.com/index.php/download_file/force/1464/1365/?market_penetration_study_0.pdf

²⁹⁷ 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.

²⁹⁸ Electric water heater have recovery efficiency of 98%:

<http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>



$$\Delta \text{kWh} = (((2.5 - 2.0) / 2.5) * 2.53 * 11.6 * 365) / 1.6 * 8.3 * (105 - 60.9) / 1,000,000 / 0.98 / 0.003412$$

$$= 147 \text{ kWh}$$

Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh/hours} * \text{CF}$$

Where:

$$\begin{aligned} \text{Hours} &= \text{Average number of hours per year spent using shower head} \\ &= (\text{Gal/person} * \# \text{ people} * 365) / \text{SH/home} / \text{GPM} / 60 \\ &= (11.6 * 2.56 * 365) / 1.6 / 2.5 / 60 \\ &= 45 \text{ hours} \\ \text{CF} &= \text{Summer Peak Coincidence Factor for measure} \\ &= 0.00371^{299} \end{aligned}$$

Illustrative example – do not use as default assumption

For a 2.0GPM rated showerhead:

$$\Delta \text{kW} = 147 / 45 * 0.00371$$

$$= 0.012 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater:

²⁹⁹ Calculated as follows: Assume 9% showers take place during peak hours (based on: http://www.aquacraft.com/Download_Reports/DISAGGREGATED-HOT_WATER_USE.pdf)
 $9\% * 7.42 \text{ minutes per day} (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 \text{ minutes}$
 $= 0.668 / 180 \text{ (minutes in peak period)} = 0.00371$



$$\Delta \text{MMBtu} = (((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \# \text{ people} * \text{gals/day} * \text{days/year}) / \text{SH/home} * 8.3 * (\text{TEMP}_{\text{sh}} - \text{TEMP}_{\text{in}}) / 1,000,000) / \text{Gas DHW Recovery Efficiency}$$

Where:

Gas DHW Recovery Efficiency = Recovery efficiency of gas water heater
= 0.75³⁰⁰

All other variables As above

Illustrative example – do not use as default assumption

For a 2.0GPM rated showerhead:

$$\begin{aligned} \Delta \text{MMBtu} &= (((2.5 - 2.0) / 2.5) * 2.53 * 11.6 * 365) / 1.6 * 8.3 * (105 - 60.9) / 1,000,000) / 0.75 \\ &= 0.65 \text{ MMBtu} \end{aligned}$$

Annual Water Savings Algorithm

$$\text{Water Savings} = (((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \# \text{ people} * \text{gals/day} * \text{days/year}) / \text{SH/home} / 748$$

Where:

748 = Constant to convert from gallons to CCF

All other variables as above

Illustrative example – do not use as default assumption

For a 2.0GPM rated showerhead:

$$\begin{aligned} \text{Water Savings} &= (((2.5 - 2.0) / 2.5) * 2.53 * 11.6 * 365) / 1.6 / 748 \\ &= 1.79 \text{ CCF} \end{aligned}$$

kWh Savings from Water Reduction

³⁰⁰Review 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.

$$\Delta \text{kWh}_{\text{water}} = 2.07 \text{ kWh/CCF} * \Delta \text{Water (CCF)}$$

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

$$\begin{aligned} \Delta \text{kWh}_{\text{water}} &= 2.07 * 1.81 \\ &= 3.7 \text{ kWh} \end{aligned}$$

Incremental Cost

As a retrofit measure, the lifecycle NPV incremental cost will be the actual cost of installing the new aerator. As a time of sale measure, the lifecycle NPV incremental cost is assumed to be \$2.³⁰¹

Measure Life

The measure life is assumed to be 10 years.³⁰²

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.

³⁰¹ Navigant Consulting, Ontario Energy Board, "Measures and Assumptions for Demand Side Management (DSM) Planning", April 2009.

³⁰² 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_0414 and RS_WT_TOS_FAUCET_0414

Effective Date: June 2014

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:

$$\Delta \text{kWh}^{303} = (((((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \# \text{ people} * \text{gals/day/person} * \text{days/year} * \text{DR}) / (\text{F/home})) * 8.3 * (\text{TEMP}_{\text{ft}} - \text{TEMP}_{\text{in}}) / 1,000,000) / \text{DHW Recovery Efficiency} / 0.003412$$

Where:

GPM_{base} = Gallons Per Minute of baseline faucet
= 2.2³⁰⁴ or actual flow rate if recorded
 GPM_{low} = Gallons Per Minute of low flow faucet

³⁰³ Note, the algorithm and variables are provided as documentation for the deemed savings result provided which should be claimed for all faucet aerator installations.

³⁰⁴ 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.



	<i>= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.</i>
<i># people</i>	<i>= Average number of people per household</i> <i>= 2.53³⁰⁵</i>
<i>gals/day/person</i>	<i>= Average gallons per day used by faucet per person</i> <i>= Time_{faucet} * GPM_{base}</i> <i>= if unknown, use 10.9³⁰⁶</i>
<i>days/y</i>	<i>= Days faucet used per year</i> <i>= 365</i>
<i>DR</i>	<i>= Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)</i> <i>= 50%³⁰⁷</i>
<i>F/home</i>	<i>= Average number of faucets in the home</i> <i>= 3.5³⁰⁸</i>
<i>8.3</i>	<i>= Constant to convert gallons to lbs</i>
<i>TEMP_{ft}</i>	<i>= Assumed temperature of water used by faucet</i> <i>= 80 Error! Bookmark not defined.</i>
<i>TEMP_{in}</i>	<i>= Assumed temperature of water entering house</i> <i>= 60.9³⁰⁹</i>
<i>DHW Recovery Efficiency</i>	<i>= Recovery efficiency of electric water heater</i> <i>= 0.98³¹⁰</i>
<i>0.003412</i>	<i>= Constant to converts MMBtu to kWh</i>

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\Delta \text{kWh} = (((2.2 - 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80 - 60.9) / 1,000,000 / 0.98 / 0.003412$$

³⁰⁵ US Energy Information Administration, Residential Energy Consumption Survey;

http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

³⁰⁶ Most commonly quoted value of gallons of water used per person per day (including in U.S.

Environmental Protection Agency's "water sense" documents;

http://www.epa.gov/watersense/docs/home_suppstat508.pdf

³⁰⁷ Estimate consistent with Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning."

³⁰⁸ Estimate based on East Bay Municipal Utility District; "Water Conservation Market Penetration Study"

http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

³⁰⁹ 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.

³¹⁰ See <http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>



$$= 219 \text{ kWh}$$

Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh/hours} * \text{CF}$$

Where:

$$\begin{aligned} \text{Hours} &= \text{Average number of hours per year spent using faucet} \\ &= (\text{Gal/person} * \# \text{ people} * 365) / (\text{F/home}) / \text{GPM} / 60 \\ &= (10.9 * 2.56 * 365) / 3.5 / 2.2 / 60 \\ &= 22 \text{ hours} \\ \text{CF} &= \text{Summer Peak Coincidence Factor for measure} \\ &= 0.00262^{311} \end{aligned}$$

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\Delta \text{kW} = 219 / 22 * 0.00262$$

$$= 0.026 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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

$$\begin{aligned} \Delta \text{MMBtu} &= (((\text{GPMbase} - \text{GPMlow}) / \text{GPMbase}) * \# \text{ people} * \text{gals/day} \\ &\quad * \text{days/year} * \text{DR}) / (\text{F/home}) * 8.3 * (\text{TEMPft} - \text{TEMPin}) / \\ &\quad 1,000,000) / \text{Gas DHW Recovery Efficiency} \end{aligned}$$

Where:

³¹¹ 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



$$\begin{aligned} \text{Gas DHW Recovery Efficiency} &= \text{Recovery efficiency of gas water heater} \\ &= 0.75^{312} \\ \text{All other variables} &\text{As above} \end{aligned}$$

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\begin{aligned} \Delta \text{MMBtu} &= (((2.2 - 1.5) / 2.2) * 2.53 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * \\ &\quad (80-60.9) / 1,000,000 / 0.75 \\ &= 0.097 \text{ MMBtu} \end{aligned}$$

Annual Water Savings Algorithm

$$\begin{aligned} \text{Water Savings} &= (((\text{GPM}_{\text{base}} - \text{GPM}_{\text{low}}) / \text{GPM}_{\text{base}}) * \# \text{ people} * \text{gals/day} \\ &\quad * \text{days/year} * \text{DR}) / (\text{F/home}) / 748 \end{aligned}$$

Where:

$$\begin{aligned} 748 &= \text{Constant to convert from gallons to CCF} \\ \text{All other variables} &\text{same as above} \end{aligned}$$

Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\begin{aligned} \text{Water Savings} &= (((2.2 - 1.5) / 2.2) * 2.53 * 10.9 * 365 * 0.5) / 3.5 / 748 \\ &= 0.612 \text{ CCF} \end{aligned}$$

kWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities' must be careful not to double count the monetary benefit of these savings within cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

$$\Delta \text{kWh}_{\text{water}}^{313} = 2.07 \text{ kWh/CCF} * \Delta \text{Water (CCF)}$$

³¹² 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%.

³¹³ 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



Illustrative example – do not use as default assumption

For a 1.5 GPM rated aerator:

$$\begin{aligned}\Delta\text{kWh}_{\text{water}} &= 2.07 \text{ kWh/CCF} * 0.619 \text{ CCF} \\ &= 1.3 \text{ kWh}\end{aligned}$$

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 \$2.³¹⁴

Measure Life

The measure life is assumed to be 5 years.³¹⁵

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.

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.

³¹⁴ Navigant Consulting, Ontario Energy Board, “Measures and Assumptions for Demand Side Management (DSM) Planning”, April 2009.

³¹⁵ Conservative estimate based on review of TRM assumptions from other States.



Domestic Hot Water Tank Wrap

Unique Measure Code(s): RS_WT_RF_HWWRAP_0113

Effective Date: June 2014

End Date: TBD

Measure Description

This measure relates to a Tank Wrap or insulation “blanket” that is wrapped around the outside of a hot water tank to reduce stand-by losses. This measure applies only for homes that have an electric water heater that is not already well insulated.

Definition of Baseline Condition

The baseline condition is a standard electric domestic hot water tank without an additional tank wrap.

Definition of Efficient Condition

The efficient condition is the same standard electric domestic hot water tank with an additional tank wrap.

Annual Energy Savings Algorithm

$$\Delta kWh = ((U_{base}A_{base} - U_{insul}A_{base}) * \Delta T * \text{Hours}) / (3412 * \eta_{DHW})$$

Where:

ΔkWh	= Gross customer annual kWh savings for the measure
U_{base}	= Overall heat transfer coefficient prior to adding tank wrap (Btu/Hr-F-ft ²) = See table below. If unknown assume 1/8 ³¹⁶
U_{insul}	= Overall heat transfer coefficient after addition of tank wrap (Btu/Hr-F-ft ²) = See table below. If unknown assume 1/18 ³¹⁷
A_{base}	= Surface area of storage tank prior to adding tank wrap (square feet) = See table below. If unknown assume 23.18 ³¹⁸

³¹⁶ Assumptions are from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM) for a poorly insulated 40 gallon tank

³¹⁷ Assumes an R-10 tank wrap is added.



A_{insul}	= Surface area of storage tank after addition of tank wrap (square feet) = See table below. If unknown assume 25.31 ³¹⁹
ΔT	= Average temperature difference between tank water and outside air temperature (°F) = 60°F ³²⁰
Hours	= Number of hours in a year (since savings are assumed to be constant over year). = 8760
3412	= Conversion from BTU to kWh
η_{DHW}	= Recovery efficiency of electric hot water heater = 0.98 ³²¹

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

³¹⁸ 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.

³¹⁹ Ibid.

³²⁰ Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

³²¹ NREL, National Residential Efficiency Measures Database,
<http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40>



50	12	20	24.99	115	0.013
50	8	18	24.99	255	0.029
50	10	20	24.99	180	0.021
50	12	22	24.99	134	0.015
80	8	16	31.84	290	0.033
80	10	18	31.84	202	0.023
80	12	20	31.84	149	0.017
80	8	18	31.84	327	0.037
80	10	20	31.84	232	0.027
80	12	22	31.84	173	0.020

If tank specifics are unknown assume 40 gallons as an average tank size³²², and savings from adding R-10 to a poorly insulated R-8 tank:

$$\begin{aligned}\Delta kWh &= ((23.18/8 - 23.18/18) * 60 * 8760) / (3412 * 0.98) \\ &= 253 \text{ kWh}\end{aligned}$$

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 size³²³, and savings are from adding R-10 to a poorly insulated R-8 tank:

$$\begin{aligned}\Delta kW &= 253 / 8760 \\ &= 0.029 \text{ kW}\end{aligned}$$

³²² 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

³²³ 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



Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure is the actual cost of installing the tank wrap. If unknown assume \$35 average cost.³²⁴

Measure Life

The measure life is assumed to be 5 years.³²⁵

Operation and Maintenance Impacts

n/a

³²⁴ Based on VEIC online product review.

³²⁵ Conservative estimate that assumes the tank wrap is installed on an existing unit with 5 years remaining life.



DHW Pipe Insulation

Unique Measure Code: RS_WT_RF_PIPEIN_0711

Effective Date: June 2014

End Date: TBD

Measure Description

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first elbow of the hot water carrying pipe.

Note, the algorithm provided to calculate savings may be used to determine an appropriate deemed savings value if the programs can provide appropriate average values for each of the variables.

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is un-insulated hot water carrying copper pipes.

Definition of Efficient Condition

To efficiency case is installing pipe wrap insulation to the first elbow of the hot water carrying copper pipe.

Annual Energy Savings Algorithm

If electric domestic hot water tank:

$$\Delta kWh = ((1/R_{exist} - 1/R_{new}) * (L * C) * \Delta T * 8,760) / \eta_{DHW} / 3413$$

Where:

R_{exist} = Assumed R-value of existing uninsulated piping
= 1.0³²⁶

R_{new} = R-value of existing pipe plus installed insulation
= Actual

³²⁶ 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



<i>Length</i>	<i>= Length of piping insulated</i> <i>= Actual</i>
<i>Circumference</i>	<i>= Circumference of piping</i> <i>= Actual (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)</i>
ΔT	<i>= Temperature difference between water in pipe and ambient air</i> <i>= 65°F³²⁷</i>
8,760	<i>= Hours per year</i>
η_{DHW}	<i>= DHW Recovery efficiency (η_{DHW})</i> <i>= 0.98³²⁸</i>
3413	<i>= Conversion from Btu to kWh</i>

Illustrative example – do not use as default assumption

Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\begin{aligned}\Delta \text{kWh} &= ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8,760) / 0.98 / 3,413 \\ &= 104 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

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

Illustrative example – do not use as default assumption

Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\begin{aligned}\Delta \text{kW} &= 104 / 8,760 \\ &= 0.012 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel DHW unit:

$$\Delta \text{MMBtu} = ((1/R_{\text{exist}} - 1/R_{\text{new}}) * (L * C) * \Delta T * 8,760) / \eta_{DHW} / 1,000,000$$

³²⁷ Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.

³²⁸ Electric water heaters have recovery efficiency of 98%:

<http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576>



Where:

$$\eta_{DHW} = \text{Recovery efficiency of gas hot water heater} \\ = 0.75^{329}$$

Illustrative example – do not use as default assumption

Insulating 4 feet of 0.75" pipe with R-3.5 wrap:

$$\Delta \text{MMBtu} = ((1/1.0 - 1/4.5) * (4 * 0.196) * 65 * 8,760) / 0.75 / 1,000,000 \\ = 0.46 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure should be the actual cost of material and labor. If this is not available, assume \$3 per foot of insulation³³⁰.

Measure Life

The measure life is assumed to be 15 years³³¹.

Operation and Maintenance Impacts

n/a

³²⁹ 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%

³³⁰ Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).

³³¹ 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 minimum³³².

For 20 - 55 gallons: $EF = 0.675 - (0.0015 * \text{rated volume in gallons})$
For 55 - 100 gallons: $EF = 0.8012 - (0.00078 * \text{rated volume in gallons})$

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 below³³³:

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

³³² 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>

³³³ 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

$$\Delta \text{MMBtu} = (1/\text{EF}_{\text{base}} - 1/\text{EF}_{\text{efficient}}) * (\text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{in}}) * 1.0) / 1,000,000$$

Where:

EF_Baseline = Energy Factor rating for baseline equipment

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 0.91³³⁴. 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

³³⁴ 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.



$$\begin{aligned} &= 45.5 \text{ gallons hot water per day per household}/2.53 \text{ people per} \\ &\text{household}^{335} \\ &= 17.6 \end{aligned}$$

$$\begin{aligned} \text{Household} &= \text{Average number of people per household} \\ &= 2.53^{336} \end{aligned}$$

$$365.25 = \text{Days per year, on average}$$

$$\begin{aligned} \gamma_{\text{Water}} &= \text{Specific Weight of water} \\ &= 8.33 \text{ pounds per gallon} \end{aligned}$$

$$\begin{aligned} T_{\text{out}} &= \text{Tank temperature} \\ &= 125^{\circ}\text{F} \end{aligned}$$

$$\begin{aligned} T_{\text{in}} &= \text{Incoming water temperature from well or municipal system} \\ &= 60.9^{337} \end{aligned}$$

$$1.0 = \text{Heat Capacity of water (1 Btu/lb}^{\circ}\text{F)}$$

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:

$$\begin{aligned} \Delta \text{MMBtu} &= (1/0.615 - 1/0.82) * (17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * \\ &1) / 1,000,000 \\ &= 3.53 \text{ MMBtu} \end{aligned}$$

Annual Water Savings Algorithm

n/a

³³⁵ 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>

³³⁶ Ibid

³³⁷ 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	\$159 ³³⁸
Condensing gas storage	\$685 ³³⁹
Tankless whole-house unit	\$407 ³⁴⁰

Measure Life

The measure life is assumed to be 13 years³⁴¹.

Operation and Maintenance Impacts

n/a

³³⁸ 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.

³³⁹ 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)

³⁴⁰ 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.

³⁴¹ 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_0415

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to the installation of a Heat Pump domestic water heater in place of a standard electric water heater in conditioned space. This is a time of sale measure.

Definition of Baseline Condition

The baseline condition is assumed to be a new electric water heater meeting federal minimum efficiency standards³⁴²:

For ≤55 gallons:	$0.96 - (0.0003 * \text{rated volume in gallons})$
For >55 gallons:	$2.057 - (0.00113 * \text{rated volume in gallons})$

Definition of Efficient Condition

The efficient condition is a heat pump water heater.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = (((1/\text{EF}_{\text{BASE}} - 1/\text{EF}_{\text{EFFICIENT}}) * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 3412) + \text{kWh}_{\text{cooling}} - \text{kWh}_{\text{heating}}$$

Where:

EF_{BASE} = Energy Factor (efficiency) of standard electric water heater according to federal standards³⁴³:

For ≤55 gallons: $0.96 - (0.0003 * \text{rated volume in gallons})$

For >55 gallons: $2.057 - (0.00113 * \text{rated volume in gallons})$

= 0.945 for a 50 gallon tank, the most common size for HPWH

³⁴² 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>

³⁴³ 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>



$EF_{EFFICIENT}$	<i>= Energy Factor (efficiency) of Heat Pump water heater</i> <i>= Actual. If unknown assume 2.0³⁴⁴</i>
GPD	<i>= Gallons Per Day of hot water use per person</i> <i>= 45.5 gallons hot water per day per household/2.53 people per household³⁴⁵</i> <i>= 17.6</i>
<i>Household</i>	<i>= Average number of people per household</i> <i>= 2.53³⁴⁶</i>
365.25	<i>= Days per year</i>
γ_{Water}	<i>= Specific weight of water</i> <i>= 8.33 pounds per gallon</i>
T_{OUT}	<i>= Tank temperature</i> <i>= 125°F</i>
T_{IN}	<i>= Incoming water temperature from well or municipal system</i> <i>= 60.9³⁴⁷</i>
1.0	<i>= Heat Capacity of water (1 Btu/lb*°F)</i>
3412	<i>= Conversion from Btu to kWh</i>

³⁴⁴ Efficiency 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

³⁴⁵ Email message from Maureen Hodgins, Research Manager for Water Research Foundation, to TAC/SAG, August 26, 2014. Describes water usage for a house size of 2.59 people.

³⁴⁶ 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>

³⁴⁷ 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.



$$\begin{aligned}
 kWh_cooling^{348} &= \text{Cooling savings from conversion of heat in home to water heat} \\
 &= (((1/EF_{NEW} * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412) * LF * 33\% / COP_{COOL})
 \end{aligned}$$

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 ³⁴⁹
COP _{COOL}	= COP of central air conditioning
	= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

$$kWh_heating = \text{Heating cost from conversion of heat in home to water heat (dependent on heating fuel)}$$

For Natural Gas heating, kWh_heating = 0

For electric heating:

$$= (((1/EF_{NEW} * GPD * Household * 365.25 * \gamma_{Water} * (T_{OUT} - T_{IN}) * 1.0) / 3412) * LF * 47\% / COP_{HEAT}$$

³⁴⁸ This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling and latent cooling demands.

³⁴⁹ 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).



Where:

47% = Portion of removed heat that results in increased heating load³⁵⁰

COP_{HEAT} = COP of electric heating system

= actual. If not available, use³⁵¹:

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:

$\Delta \text{kWh electric resistance heat} = (((1/0.945 - 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) + \text{kWh_cooling} - \text{kWh_heating}$

$\text{kWh_cooling} = ((1/ 2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) * 0.5 * 0.33) / 3.08) * 1.33$

= 90.7 kWh

$\text{kWh_heating} = ((1/ 2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) * 0.5 * 0.47) / 1.0$

³⁵⁰ 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).

³⁵¹ 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.



$$= 299.1 \text{ kWh}$$

$$\begin{aligned} \Delta \text{kWh electric resistance heat} &= 1420.7 + 90.7 - 299.1 \\ &= 1212.3 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh heat pump heat} &= (((1/0.945 - 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * \\ &\quad (125 - 60.9) * 1.0) / 3412) + \text{kWh_cooling} - \\ &\quad \text{kWh_heating} \end{aligned}$$

$$\text{kWh_cooling} = 90.7 \text{ kWh}$$

$$\begin{aligned} \text{kWh_heating} &= ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * \\ &\quad (125 - 60.9) * 1.0) / 3412) * 0.5 * 0.47) / 2.0 \\ &= 149.5 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh heat pump heat} &= 1420.7 + 90.7 - 149.5 \\ &= 1361.9 \text{ kWh} \end{aligned}$$

$$\begin{aligned} \Delta \text{kWh fossil fuel heat} &= (((1/0.945 - 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * \\ &\quad (125 - 60.9) * 1.0) / 3412) + \text{kWh_cooling} - \\ &\quad \text{kWh_heating} \end{aligned}$$

$$\text{kWh_cooling} = 90.7$$

$$\text{kWh_heating} = 0$$

$$\begin{aligned} \Delta \text{kWh fossil fuel heat} &= 1420.7 + 90.7 - 0 \\ &= 1511.4 \text{ kWh} \end{aligned}$$

Summer Coincident Peak kW Savings Algorithm



$$\Delta kW = 0.17 \text{ kW}^{352}$$

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBtu} = - \left(\left(\frac{1}{\text{EF}_{\text{NEW}}} * \text{GPD} * \text{Household} * 365.25 * \gamma_{\text{Water}} * (T_{\text{OUT}} - T_{\text{IN}}) * 1.0 \right) / 3412 \right) * \text{LF} * 47\% * 0.003412 / (\eta_{\text{Heat}} * \% \text{ Natural Gas})$$

Where:

ΔMMBtu = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat.³⁵³

0.003412 = conversion factor (MMBtu per kWh)

η_{Heat} = Efficiency of heating system

= Actual.³⁵⁴ If not available, use 84%.³⁵⁵

% Natural Gas = Factor dependent on heating fuel:

Heating System	%Natural Gas
Electric resistance or heat pump	0%
Natural Gas	100%
Unknown heating fuel ³⁵⁶	62.5%

³⁵² 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.

³⁵³ 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.

³⁵⁴ 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.

³⁵⁵ 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>).



Other factors as defined above

Prescriptive savings based on defaults provided above:

ΔMMBtu for fossil fuel heated homes:

$$\begin{aligned}\Delta\text{MMBtu} &= - ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * \\ &1.0) / 3412)) * 0.5 * 0.47 * 0.003412) / (0.72 * 1.0) \\ &= - 1.21\text{MMBtu}\end{aligned}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for the time of sale measure is provided below.³⁵⁷

Size	Efficiency Factor	Incremental Cost per Unit
40 Gallon Heat Pump Water Heater	2	\$1,338
60 Gallon Heat Pump Water Heater	2.2	\$2,253

Measure Life

The expected measure life is assumed to be 13 years.³⁵⁸

Operation and Maintenance Impacts

³⁵⁶ Based on KEMA baseline study for Maryland.

³⁵⁷ Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 – 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA.

³⁵⁸ 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



REGIONAL EVALUATION,
MEASUREMENT & VERIFICATION FORUM

n/a



Thermostatic Restrictor Shower Valve

Unique Measure Code: RS_HV_RF_GSHPS_0415, RS_HV_NC_GSHPS_0415

Effective Date: June 2015

End Date: TBD

Measure Description

The measure is the installation of a thermostatic restrictor shower valve in a single or multi-family household. This is a valve attached to a residential showerhead which restricts hot water flow through the showerhead once the water reaches a set point (generally 95F or lower).

This measure was developed to be applicable to the following program types: RF, NC, DI. If applied to other program types, the measure savings should be verified.

Definition of Baseline Condition

The baseline equipment is the residential showerhead without the restrictor valve installed.

Definition of Efficient Condition

To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = \% \text{ElectricDHW} * ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{EPG_electric}$$

Where:

%ElectricDHW = proportion of water heating supplied by electric resistance heating

DHW fuel	%ElectricDHW
Electric	100%
Natural Gas	0%
Unknown	24% ³⁵⁹

³⁵⁹ 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

<i>Program</i>	<i>GPM</i>
<i>Direct-install, device only</i>	<i>2.5³⁶⁰</i>
<i>New Construction or direct install of device and low flow showerhead</i>	<i>Rated or actual flow of program-installed showerhead</i>

L_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

= 0.89 minutes³⁶¹

Household = Average number of people per household

= 2.56³⁶²

SPCD = Showers Per Capita Per Day

= 0.6³⁶³

365.25 = Days per year, on average.

SPH = Showerheads Per Household so that per-showerhead savings fractions can be determined

= 1.6³⁶⁴

³⁶⁰ The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

³⁶¹ 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.

³⁶² US Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

³⁶³ Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.

³⁶⁴ Estimate based on review of a number of studies:



$$\begin{aligned} EPG_electric &= \text{Energy per gallon of hot water supplied by electric} \\ &= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412) \\ &= (8.33 * 1.0 * (105 - 60.9)) / (0.98 * 3412) \\ &= 0.11 \text{ kWh/gal} \\ 8.33 &= \text{Specific weight of water (lbs/gallon)} \\ 1.0 &= \text{Heat Capacity of water (btu/lb-}^\circ\text{)} \\ ShowerTemp &= \text{Assumed temperature of water} \\ &= 105F^{365} \\ SupplyTemp &= \text{Assumed temperature of water entering house} \\ &= 60.9^{366} \\ RE_electric &= \text{Recovery efficiency of electric water heater} \\ &= 98\%^{367} \\ 3412 &= \text{Constant to convert Btu to kWh} \end{aligned}$$

Illustrative Example - do not use as default assumption

For example, a direct installed valve in a home with electric DHW:

a. Pacific Northwest Laboratory; "Energy Savings from Energy-Efficient Showerheads: REMP Case Study Results, Proposed Evaluation Algorithm, and Program Design Implications"
<http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=80456EF00AAB94DB204E848BAE65F199?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

³⁶⁵ 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.

³⁶⁶ 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.

³⁶⁷ Electric water heaters have recovery efficiency of 98%:
<http://www.ahridirectory.org/ahridirectory/pages/home.aspx>



$$\begin{aligned}\Delta \text{kWh} &= 1.0 * (2.5 * 0.89 * 2.56 * 0.6 * 365.25 / 1.6) * 0.11 \\ &= 86 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device

$$= ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * 0.746^{368} / \text{GPH}$$

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.

$$= 30.0$$

$$\begin{aligned}\text{Hours} &= ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.746 / 30 \\ &= 19.4 \text{ hours}\end{aligned}$$

$$\begin{aligned}\text{CF} &= \text{Coincidence Factor for electric load reduction} \\ &= 0.0015^{369}\end{aligned}$$

³⁶⁸ 74.6% is the proportion of hot 120F water mixed with 60.1F supply water to give 105F shower water.

³⁶⁹ 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 $0.38 / 260 = 0.0015$



Illustrative example – do not use as default assumption

For example, a direct installed valve in a home with electric DHW:

$$\Delta kW = 86 / 19.4 * 0.0015$$

$$= 0.007 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBtu} = \% \text{FossilDHW} * ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) * \text{EPG_gas}$$

Where:

%FossilDHW = proportion of water heating supplied by Natural Gas heating

DHW fuel	%Fossil_DHW
Electric	0%
Natural Gas	100%
Unknown	76% ³⁷⁰

EPG_gas = Energy per gallon of Hot water supplied by gas

$$= (8.33 * 1.0 * (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE_gas} * 1,000,000)$$

$$= 0.00065 \text{ MMBtu/gal}$$

RE_gas = Recovery efficiency of gas water heater

$$= 75\% \text{ For SF homes}^{371}$$

³⁷⁰ 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.

³⁷¹ 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



$1,000,000$ = Converts Btus to MMBtu

Other variables as defined above.

Illustrative example – do not use as default assumption

For example, a direct installed valve in a home with gas DHW:

$$\begin{aligned}\Delta \text{MMBTu} &= 1.0 * ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.00065 \\ &= 0.51 \text{ MMBtu}\end{aligned}$$

Water impact Descriptions and calculations

$$\Delta \text{CCF} = ((\text{GPM_base_S} * \text{L_showerdevice}) * \text{Household} * \text{SPCD} * 365.25 / \text{SPH}) / 748$$

Where:

748 = Constant to convert from gallons to CCF

Other variables as defined above

Illustrative example – do not use as default assumption

For example, a direct installed valve:

$$\begin{aligned}\Delta \text{CCF} &= ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) / 748 \\ &= 1.0 \text{ CCF}\end{aligned}$$

Measure Life

The expected measure life is assumed to be 10 years.³⁷²

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is the actual measure cost or \$30³⁷³ if not available.

Operation and Maintenance Impacts

N/A

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%.

³⁷² Assumptions based on NY TRM, Pacific Gas and Electric Company Work Paper PGECODHW113, and measure life of low-flow showerhead

³⁷³ 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:

$$\Delta \text{kWh}^{374} = (UA * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours}) / (3412 * \text{RE}_{\text{electric}})$$

Where:

U = Overall heat transfer coefficient of tank (Btu/Hr-°F-ft²).

= Actual if known. If unknown assume R-12, $U = 0.083$

A = Surface area of storage tank (square feet)

³⁷⁴ 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

<i>Capacity (gal)</i>	<i>A (ft²)³⁷⁵</i>
30	19.16
40	23.18
50	24.99
80	31.84

T_{pre} = Actual hot water setpoint prior to adjustment.

= 135 degrees default

T_{post} = Actual new hot water setpoint, which may not be lower than 120 degrees

= 120 degrees default

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8760

3412 = Conversion from Btu to kWh

RE_{electric} = Recovery efficiency of electric hot water heater

= 0.98³⁷⁶

The deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\Delta kWh = (UA * (T_{pre} - T_{post}) * Hours) / (3412 * RE_{electric})$$

³⁷⁵ 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.

³⁷⁶ Electric water heaters have recovery efficiency of 98%:

<http://www.ahridirectory.org/ahridirectory/pages/home.aspx>



$$\begin{aligned} &= (((0.083 * 24.99) * (135 - 120) * 8760) / (3412 * 0.98)) \\ &= 81.5 \text{ kWh} \end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours}$$

Where:

$$\text{Hours} = 8760$$

The deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\begin{aligned} \Delta \text{kW} &= (81.5 / 8760) \\ &= 0.0093 \text{ kW} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

For homes with gas water heaters:

$$\Delta \text{MMBtu} = (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours}) / (1,000,000 * RE_{\text{gas}})$$

Where

$$1,000,000 = \text{Converts Btus to MMBtu (btu/MMBtu)}$$

$$\begin{aligned} RE_{\text{gas}} &= \text{Recovery efficiency of gas water heater} \\ &= 0.75^{377} \end{aligned}$$

The deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\begin{aligned} \Delta \text{MMBtu} &= (U * A * (T_{\text{pre}} - T_{\text{post}}) * \text{Hours}) / (1,000,000 * RE_{\text{gas}}) \\ &= (0.083 * 24.99 * (135 - 120) * 8760) / (1,000,000 * 0.75) \\ &= 0.36 \text{ MMBtu} \end{aligned}$$

³⁷⁷Review 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	$\geq 2.06^{378}$	≤ 3.7	$\leq 4.3^{379}$
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, 2018³⁸⁰. 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.

³⁷⁸ CEE does not distinguish between front loading and top loading, and requires a minimum IMEF of 2.38 in both cases

³⁷⁹ CEE does not distinguish between front loading and top loading, and requires a maximum IWF of 3.7 in both cases

³⁸⁰

<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

$$\Delta kWh = [(Capacity * 1/IMEF_{base} * N_{cycles}) * (\%CW_{base} + (\%DHW_{base} * \%Electric_DHW) + (\%Dryer_{base} * \%Electric_Dryer))] - [(Capacity * 1/IMEF_{eff} * N_{cycles}) * (\%CW_{eff} + (\%DHW_{eff} * \%Electric_DHW) + (\%Dryer_{eff} * \%Electric_Dryer))]$$

Where

Capacity = Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume average 3.45 cubic feet³⁸¹

³⁸¹ Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/28/2014.



IMEF_{base} = Integrated Modified Energy Factor of baseline unit
= Values provided in table below

IMEF_{eff} = Integrated Modified Energy Factor of efficient unit
= Actual. If unknown assume average values provided below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages ³⁸²	
	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%

N_{cycles} = Number of Cycles per year
= 254³⁸³

%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 ³⁸⁴		
%CW	%DHW	%Dryer

³⁸² Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

³⁸³ 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.

³⁸⁴ 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.xls m. See “2015 Clothes Washer Analysis.xls” for the calculation.



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%	76%

%Electric_DHW = Percentage of DHW savings assumed to be electric

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	65% ³⁸⁵

%Electric_Dryer = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%
Unknown	79% ³⁸⁶

The prescriptive kWh savings based on values provided above where DHW and Dryer fuels are unknown is provided below³⁸⁷:

Efficiency Level	Δ kWh		
	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

³⁸⁵ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

³⁸⁶ 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.

³⁸⁷ Note that the baseline savings for all cases (Front, Top and Weighted Average) is based on the weighted average baseline IMEF (as opposed to assuming Front baseline for Front efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.



Efficiency Level	ΔkWh		
	Front	Top	Weighted Average
CEE TIER 3	160.9	n/a	160.9

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

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

$$\begin{aligned} \text{Hours} &= \text{Assumed Run hours of Clothes Washer} \\ &= 265^{388} \end{aligned}$$

³⁸⁸ 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.



$$CF = \text{Summer Peak Coincidence Factor for measure} \\ = 0.029^{389}$$

The prescriptive kW savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	ΔkW		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	0.012	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

$$\Delta \text{MMBtu} = [(Capacity * 1/IMEF_{base} * N_{cycles}) * ((\%DHW_{base} * \%Natural\ Gas_DHW * R_{eff}) + (\%Dryer_{base} * \%Gas_Dryer))] - [(Capacity * 1/IMEF_{eff} * N_{cycles}) * ((\%DHW_{eff} * \%Natural\ Gas_DHW * R_{eff}) + (\%Dryer_{eff} * \%Gas_Dryer))] * \text{MMBtu_convert}$$

³⁸⁹ Ibid.



Where:

R_{eff} = Recovery efficiency factor
= 1.31³⁹⁰

$MMBtu_convert$ = 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% ³⁹¹

$\%Gas_Dryer$ = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	6% ³⁹²

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	$\Delta MMBtu$		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	0.16	0.05	0.12

³⁹⁰ To account for the different efficiency of electric and Natural Gas water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf). Therefore, a factor of 0.98/0.78 (1.26) is applied.

³⁹¹ 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.

³⁹² 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	Δ MMBtu		
	Front	Top	Weighted Average
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:

Efficiency Level	Configuration	Δ MMBtu		
		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

$$\Delta \text{Water (CCF)} = (\text{Capacity} * (\text{IWF}_{\text{base}} - \text{IWF}_{\text{eff}})) * \text{Ncycles} / 748 \text{ gallons/CCF}$$

Where

IWF_{base} = Integrated Water Factor of baseline clothes washer
= Values provided below (gallons/CF of washer capacity)

IWF_{eff} = Integrated Water Factor of efficient clothes washer (gallons/CF of washer capacity)

= Actual. If unknown assume average values provided below.



Efficiency Level	IWF ³⁹³		
	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

The prescriptive water savings for each efficiency level are presented below:

Efficiency Level	Δ Water (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.

$$\Delta \text{kWh}_{\text{water}}^{394} = 2.07 \text{ kWh} * \Delta \text{Water (CCF)}$$

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	$\Delta \text{kWh}_{\text{water}}$
------------------	------------------------------------

³⁹³ Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

³⁹⁴ 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.



	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:³⁹⁵

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 years³⁹⁶.

Operation and Maintenance Impacts

n/a

³⁹⁵ 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

³⁹⁶ 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	$\geq 2.06^{397}$	≤ 3.7	$\leq 4.3^{398}$
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.

³⁹⁷ CEE does not distinguish between front loading and top loading, and requires a minimum IMEF of 2.38 in both cases

³⁹⁸ 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 years³⁹⁹, 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)

³⁹⁹ Based on 1/3 of the measure life.



$$\Delta kWh = [(Capacity * 1/IMEF_{base} * N_{cycles}) * (\%CW_{base} + (\%DHW_{base} * \%Electric_DHW) + (\%Dryer_{base} * \%Electric_Dryer))] - [(Capacity * 1/IMEF_{eff} * N_{cycles}) * (\%CW_{eff} + (\%DHW_{eff} * \%Electric_DHW) + (\%Dryer_{eff} * \%Electric_Dryer))]$$

Where

Capacity = Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume average 3.45 cubic feet⁴⁰⁰

IMEF_{base} = Integrated Modified Energy Factor of baseline unit
= Values provided in table below

IMEF_{eff} = Integrated Modified Energy Factor of efficient unit
= Actual. If unknown assume average values provided below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages ⁴⁰¹	
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading
Existing Unit ⁴⁰²	1.0	0.84	n/a ⁴⁰³	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
= 254⁴⁰⁴

%CW = Percentage of total energy consumption for Clothes Washer operation

⁴⁰⁰ 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.

⁴⁰¹ Weighting percentages are based on available product from the CEC database.

⁴⁰² Existing units efficiencies are based upon an MEF of 1.26 , the 2004 Federal Standard, converted to IMEF using an ENERGY STAR conversion tool.

⁴⁰³ For early replacement measures we will always know the configuration of the replaced machine.

⁴⁰⁴ 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.



%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 ⁴⁰⁵		
	%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)	Remaining measure life (next 9 years)	Mid Life Adjustment	Equivalent Weighted Average Annual
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⁴⁰⁵ 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.



		Δ kWH		Δ kWH			Savings	
		Front	Top	Weighted Average	Front	Top	Front	Top
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

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

Hours = Assumed Run hours of Clothes Washer
= 265⁴⁰⁶

CF = Summer Peak Coincidence Factor for measure
= 0.029⁴⁰⁷

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) Δ kW	Remaining measure life (next 9 years) Δ kW	Mid Life Adjustment	Equivalent Weighted Average Annual Savings
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⁴⁰⁶ 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.

⁴⁰⁷ Ibid.



		Front	Top	Weighted Average	Front	Top	Front	Top
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.053	0.072	0.015	29%	21%	0.033	0.042
	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:

$$\Delta \text{MMBtu} = [(\text{Capacity} * 1/\text{IMEF}_{\text{base}} * \text{Ncycles}) * ((\% \text{DHW}_{\text{base}} * \% \text{Natural Gas}_{\text{DHW}} * R_{\text{eff}}) + (\% \text{Dryer}_{\text{base}} * \% \text{Gas}_{\text{Dryer}}))] - [(\text{Capacity} * 1/\text{IMEF}_{\text{eff}} * \text{Ncycles}) * ((\% \text{DHW}_{\text{eff}} * \% \text{Natural Gas}_{\text{DHW}} * R_{\text{eff}}) + (\% \text{Dryer}_{\text{eff}} * \% \text{Gas}_{\text{Dryer}}))] * \text{MMBtu}_{\text{convert}}$$

Where:

$$R_{\text{eff}} = \text{Recovery efficiency factor} \\ = 1.26^{408}$$

$$\text{MMBtu}_{\text{convert}} = \text{Conversion factor from kWh to MMBtu} \\ = 0.003413$$

⁴⁰⁸ 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.



%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%

Other factors as defined above

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Efficiency Level	Configuration	Remaining life of existing unit (first 5 years) ΔMMBtu		Remaining measure life (next 9 years) ΔMMBtu	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top	Weighted Average	Front	Top	Front	Top
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.00	0.00	0.00	n/a	n/a	0.00	0.00
	Electric Dryer/Gas DHW	0.74	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



$$\Delta\text{Water (CCF)} = (\text{Capacity} * (\text{IWF}_{\text{base}} - \text{IWF}_{\text{eff}})) * \text{Ncycles} / 748 \text{ gallons / CCF}$$

Where

WF_{base} = Integrated Water Factor of baseline clothes washer
= Values provided below

WF_{eff} = Integrated Water Factor of efficient clothes washer
= Actual. If unknown assume average values provided below.

Efficiency Level	IWF^{409}		
	Front Loading	Top Loading	Weighted Average
Existing ⁴¹⁰	8.2	8.4	n/a ⁴¹¹
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 below⁴¹²:

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
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⁴⁰⁹ Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database.

⁴¹⁰ 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.

⁴¹¹ For early replacement measures we will always know the configuration of the replaced machine.

⁴¹² 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/>)



	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
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.

$$\Delta \text{kWh}_{\text{water}}^{413} = 2.07 \text{ kWh} * \Delta \text{Water (CCF)}$$

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	Remaining life of existing unit (first 5 years) $\Delta \text{Water (ccf per year)}$		Remaining measure life (next 9 years) $\Delta \text{Water (ccf per year)}$	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

⁴¹³ 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.



Incremental Cost

The lifecycle NPV incremental cost for this early replacement measure is provided in the table below:⁴¹⁴

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 years⁴¹⁵ and the existing unit is assumed to have a remaining life of 5 years⁴¹⁶.

Operation and Maintenance Impacts

n/a

⁴¹⁴ 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

⁴¹⁵ 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

⁴¹⁶ Based on 1/3 of the measure life.



Dehumidifier

Unique Measure Code(s): RS_AP_TOS_DEHUMID_0113

Effective Date: June 2014

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)⁴¹⁷ 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 (L/kWh) ⁴¹⁸
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

Definition of Efficient Condition

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards version 4.0 effective 10/25/2016⁴¹⁹ as defined below:

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
<75	≥2.00
75 to ≤185	≥2.80

⁴¹⁷ Energy Star Version 4.0 became effective 10/25/16

⁴¹⁸ 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>

⁴¹⁹https://www.energystar.gov/products/spec/dehumidifiers_specification_version_4_0_pd



Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = \text{Capacity} * 0.473 / 24 * \text{Hours} * (1 / (\text{L/kWh}_{\text{Base}}) - 1 / (\text{L/kWh}_{\text{Eff}}))$$

Where:

<i>Capacity</i>	= Capacity of the unit (pints/day)
<i>0.473</i>	= Constant to convert Pints to Liters
<i>24</i>	= Constant to convert Liters/day to Liters/hour
<i>Hours</i>	= Run hours per year = 1632 ⁴²⁰
<i>L/kWh</i>	= Liters of water per kWh consumed, as provided in tables above

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

⁴²⁰ 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



> 54 to ≤ 75	65	1.7	2.0	1230	1045	184
> 75 to ≤ 185	130	2.5	2.8	1673	1493	179
Average	46	1.51	2.0	983	740	240

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

Hours = Annual operating hours
= 1632 hours⁴²¹
CF = Summer Peak Coincidence Factor for measure
= 0.37⁴²²

Capacity	ΔkW
(pints/day) Range	
≤25	0.035
> 25 to ≤35	0.053
> 35 to ≤45	0.049
> 45 to ≤ 54	0.046
> 54 to ≤ 75	0.042
> 75 to ≤ 185	0.041
Average	0.054

Annual Fossil Fuel Savings Algorithm

n/a

⁴²¹ 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

⁴²² 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%



Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$5⁴²³.

Measure Life

The measure life is assumed to be 12 years.⁴²⁴

Operation and Maintenance Impacts

n/a

⁴²³ 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

⁴²⁴ ENERGY STAR Dehumidifier Calculator

http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b



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, 2011⁴²⁵.

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 Dust⁴²⁶ 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

⁴²⁵ 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

⁴²⁶ Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard



$$\Delta \text{kWh} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}$$

Where:

kWh_{BASE} = Baseline kWh consumption per year⁴²⁷

= see table below

$\text{kWh}_{\text{ESTAR}}$ = ENERGY STAR kWh consumption per year⁴²⁸

= 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

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5840 hours⁴²⁹

⁴²⁷ 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.

⁴²⁸ Ibid.

Efficiency 3.0 CADR/Watt, 16 hours a day, 365 days a year and 0.6W standby power.



CF = Summer Peak Coincidence Factor for measure
= 0.67⁴³⁰

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 \$0.⁴³¹

Measure Life

The measure life is assumed to be 9 years⁴³².

Operation and Maintenance Impacts

There are no operation and maintenance cost adjustments for this measure.⁴³³

⁴²⁹ Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

⁴³⁰ Assumes appliance use is equally likely at any hour of the day or night.

⁴³¹ ENERGY STAR Appliance Savings Calculator, which cites “EPA research on available models, 2012”

⁴³² ENERGY STAR Appliance Savings Calculator; Based on Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

⁴³³ 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 dryers⁴³⁴. 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

$$\Delta \text{kWh} = (\text{Load}/\text{CEF}_{\text{base}} - \text{Load}/\text{CEF}_{\text{eff}}) * \text{Ncycles} * \% \text{Electric}$$

Where:

Load = The average total weight (lbs) of clothes per drying cycle.
If dryer size is unknown, assume standard.

⁴³⁴ 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



<i>Dryer Size</i>	<i>Load (lbs.)⁴³⁵</i>
<i>Standard</i>	<i>8.45</i>
<i>Compact</i>	<i>3</i>

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 analysis⁴³⁶. If product class unknown, assume electric, standard.

<i>Product Class</i>	<i>CEFbase (lbs/kWh)</i>
<i>Vented Electric, Standard (≥ 4.4 ft³)</i>	<i>3.11</i>
<i>Vented Electric, Compact (120V) (< 4.4 ft³)</i>	<i>3.01</i>
<i>Vented Electric, Compact (240V) (< 4.4 ft³)</i>	<i>2.73</i>
<i>Ventless Electric, Compact (240V) (< 4.4 ft³)</i>	<i>2.13</i>
<i>Vented Gas</i>	<i>2.84⁴³⁷</i>

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.⁴³⁸ If product class unknown, assume electric, standard.

<i>Product Class</i>	<i>CEFeff (lbs/kWh)</i>
<i>Vented or Ventless Electric, Standard (≥ 4.4 ft³)</i>	<i>3.93</i>
<i>Vented or Ventless Electric, Compact (120V) (< 4.4 ft³)</i>	<i>3.80</i>
<i>Vented Electric, Compact (240V) (< 4.4 ft³)</i>	<i>3.45</i>
<i>Ventless Electric, Compact (240V) (< 4.4 ft³)</i>	<i>2.68</i>
<i>Vented Gas</i>	<i>3.48⁴³⁹</i>

Ncycles = Number of dryer cycles per year
= 311 cycles per year.⁴⁴⁰

⁴³⁵ Based on ENERGY STAR test procedures.

https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

⁴³⁶ ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

⁴³⁷ Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

⁴³⁸ ENERGY STAR Clothes Dryers Key Product Criteria.

https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

⁴³⁹ Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.



%Electric = The percent of overall savings coming from electricity

<i>Clothes Dryer Fuel Type</i>	<i>%Electric</i> ⁴⁴¹
<i>Electric</i>	<i>100%</i>
<i>Gas</i>	<i>16%</i>

Product Class	Algorithm	ΔkWh
<i>Vented or Ventless Electric, Standard (≥ 4.4 ft³)</i>	$= ((8.45/3.11 - 8.45/3.93) * 311 * 100\%)$	176.3
<i>Vented or Ventless Electric, Compact (120V) (< 4.4 ft³)</i>	$= ((3/3.01 - 3/3.80) * 311 * 100\%)$	64.4
<i>Vented Electric, Compact (240V) (< 4.4 ft³)</i>	$= ((3/2.73 - 3/3.45) * 311 * 100\%)$	71.3
<i>Ventless Electric, Compact (240V) (< 4.4 ft³)</i>	$= ((3/2.13 - 3/2.68) * 311 * 100\%)$	89.9
<i>Vented Gas</i>	$= ((8.45/2.84 - 8.45/3.48) * 311 * 16\%)$	27.2

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer.

=290 hours per year.⁴⁴²

CF = Summer Peak Coincidence Factor for measure

= 2.9%⁴⁴³

Product Class	Algorithm	ΔkW
<i>Vented or Ventless Electric, Standard (≥ 4.4 ft³)</i>	$= 176.3/290 * 0.029$	0.018
<i>Vented or Ventless Electric, Compact (120V) (< 4.4 ft³)</i>	$= 64.4/290 * 0.029$	0.006
<i>Vented Electric, Compact (240V) (< 4.4 ft³)</i>	$= 71.3/290 * 0.029$	0.007

⁴⁴⁰ Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014.

⁴⁴¹ %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.

⁴⁴² Assumes average of 56 minutes per cycle based on Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014

⁴⁴³ 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.



<i>Ventless Electric, Compact (240V) (< 4.4 ft³)</i>	$= 89.9/290 * 0.029$	0.009
<i>Vented Gas</i>	$= 27.2/290 * 0.029$	0.003

Annual Fossil Fuel Savings Algorithm

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

$$\Delta \text{MMBtu} = (\text{Load}/\text{CEF}_{\text{base}} - \text{Load}/\text{CEF}_{\text{eff}}) * \text{Ncycles} * \text{MMBtu}_{\text{convert}} * \% \text{Gas}$$

Where:

$$\text{MMBtu}_{\text{convert}} = \text{Conversion factor from kWh to MMBtu} \\ = 0.003413$$

$$\% \text{Gas} = \text{Percent of overall savings coming from gas}$$

<i>Clothes Dryer Fuel Type</i>	<i>%Gas⁴⁴⁴</i>
<i>Electric</i>	<i>0%</i>
<i>Gas</i>	<i>84%</i>

Product Class	Algorithm	ΔMMBtu
<i>Vented or Ventless Electric, Standard ($\geq 4.4 \text{ ft}^3$)</i>	n/a	0
<i>Vented or Ventless Electric, Compact (120V) (< 4.4 ft³)</i>	n/a	0
<i>Vented Electric, Compact (240V) (< 4.4 ft³)</i>	n/a	0
<i>Ventless Electric, Compact (240V) (< 4.4 ft³)</i>	n/a	0
<i>Vented Gas</i>	$= (8.45/2.84 - 8.45/3.48) * 311 * 0.003413 * 0.84$	0.49

Annual Water Savings Algorithm

n/a

Incremental Cost

⁴⁴⁴ %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.



The lifecycle NPV incremental cost for a time of sale ENERGY STAR clothes dryer is assumed to be \$75.⁴⁴⁵

Measure Life

The expected measure life is assumed to be 14 years⁴⁴⁶.

Operation and Maintenance Impacts

n/a

⁴⁴⁵ Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”

⁴⁴⁶ 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 below⁴⁴⁷:

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

$$\Delta \text{kWh}^{448} = ((\text{kWh}_{\text{BASE}} - \text{kWh}_{\text{ESTAR}}) * (\% \text{kWh}_{\text{op}} + (\% \text{kWh}_{\text{heat}} * \% \text{Electric_DHW})))$$

Where:

$$\text{kWh}_{\text{BASE}} = \text{Baseline kWh consumption per year}$$

⁴⁴⁷ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

⁴⁴⁸ 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.



$$= 307 \text{ kWh}$$

$$kWh_{ESTAR} = \text{ENERGY STAR kWh annual consumption} = 270$$

$$\%kWh_{op} = \text{Percentage of dishwasher energy consumption used for unit operation}$$

$$= 1 - 56\%^{449}$$

$$= 44\%$$

$$\%kWh_{heat} = \text{Percentage of dishwasher energy consumption used for water heating}$$

$$= 56\%^{450}$$

$$\%Electric_DHW = \text{Percentage of DHW savings assumed to be electric}$$

DHW fuel	%Electric_DHW
Electric	100%
Natural Gas	0%
Unknown	65% ⁴⁵¹

DHW Fuel	Algorithm	ΔkWh
Electric	$= ((307 - 270) * (0.44 + (0.56 * 1.0)))$	37
Unknown	$= ((307 - 270) * (0.44 + (0.56 * 0.65)))$	29.7

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

$$\text{Hours} = \text{Annual operating hours}^{452}$$

⁴⁴⁹ ENERGY STAR Dishwasher Calculator, see 'EnergyStarCalculatorConsumerDishwasher.xls'.

⁴⁵⁰ Ibid.

⁴⁵¹ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the Mid-Atlantic region.



$$= 210 \text{ hours}$$

$$CF = \text{Summer Peak Coincidence Factor}$$

$$= 2.6\%^{453}$$

DHW Fuel	Algorithm	ΔkW
Electric	$= 37/210 * 0.026$	0.0046
Unknown	$= 29.75/210 * 0.02$	0.0037

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBtu} = (\text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}) * \% \text{kWh}_{\text{heat}} * \% \text{Natural Gas}_{\text{DHW}} * R_{\text{eff}} * 0.003413$$

Where

$$\% \text{kWh}_{\text{heat}} = \% \text{ of dishwasher energy used for water heating}$$

$$= 56\%$$

$$\% \text{Natural Gas}_{\text{DHW}} = \text{Percentage of DHW savings assumed to be Natural Gas}$$

DHW fuel	%Natural Gas _{DHW}
Electric	0%
Natural Gas	100%
Unknown	35% ⁴⁵⁴

⁴⁵² 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/>

⁴⁵³ 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.

⁴⁵⁴ 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.



$$R_{eff} = \text{Recovery efficiency factor}$$

$$= 1.31^{455}$$

$$0.003413 = \text{factor to convert from kWh to MMBtu}$$

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

$$\Delta CCF = (\text{Water}_{Base} - \text{Water}_{EFF}) * \text{GalToCCF}$$

Where

$$\text{Water}_{Base} = \text{annual water consumption of conventional unit}$$

$$= 700 \text{ gallons}^{456}$$

$$\text{Water}_{EFF} = \text{annual water consumption of efficient unit:}$$

ENERGY STAR Specification	WaterEFF (gallons)
6.0	490 ⁴⁵⁷

$$\text{GalToCCF} = \text{factor to convert from gallons to CCF}$$

⁴⁵⁵ 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.

⁴⁵⁶ 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/>

⁴⁵⁷ 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/>



$$= 0.001336$$

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 \$0⁴⁵⁸.

Measure Life

The measure life is assumed to be 10 years⁴⁵⁹.

Operation and Maintenance Impacts

n/a

⁴⁵⁸ Energy Star Appliance Calculator, which cites “Cadmus Research on available models, July 2016.”

⁴⁵⁹ 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 practices⁴⁶⁰. 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

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

⁴⁶⁰ See BPI Building Analyst and Envelope Professional standards,
http://www.bpi.org/standards_approved.aspx



Cooling savings from reduction in Air Conditioning Load:

$$\Delta kWh_{cool} = [(((CFM50Exist - CFM50New) / N_{cool}) * 60 * CDH * DUA * 0.018) / 1,000 / \eta_{Cool}] * LM$$

Where:

CFM50exist = Blower Door result (*CFM₅₀*) prior to air sealing
= actual

CFMnew = Blower Door result (*CFM₅₀*) after air sealing
= actual

N-cool = conversion from *CFM₅₀* to *CFM_{Natural}*⁴⁶¹
= dependent on location and number of stories:⁴⁶²

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 Hours⁴⁶³
= dependent on location:

Location	Cooling Degree Hours (75°F set point)
----------	---------------------------------------------

⁴⁶¹ 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>

⁴⁶² 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".

⁴⁶³ 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)



<i>Wilmington, DE</i>	<i>7,514</i>
<i>Baltimore, MD</i>	<i>9,616</i>
<i>Washington, DC</i>	<i>13,178</i>

DUA = Discretionary Use Adjustment⁴⁶⁴
= 0.75

0.018 = The volumetric heat capacity of air (Btu/ft³F)
ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available, use⁴⁶⁵:

<i>Age of Equipment</i>	<i>SEER Estimate</i>
<i>Before 2006</i>	<i>10</i>
<i>After 2006</i>	<i>13</i>

LM = Latent Multiplier to account for latent cooling demand⁴⁶⁶

<i>Location</i>	<i>LM</i>
<i>Wilmington, DE</i>	<i>4.09</i>
<i>Baltimore, MD</i>	<i>3.63</i>
<i>Washington, DC</i>	<i>3.63</i>

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.

$$\begin{aligned}\Delta \text{kWh}_{\text{cool}} &= [(((3,400 - 2,250) / 38.4) * 60 * 7,514 * \\ &\quad 0.75 * 0.018) / 1,000 / 12] * 4.09 \\ &= 62.1 \text{ kWh}\end{aligned}$$

⁴⁶⁴ 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.

⁴⁶⁵ 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.

⁴⁶⁶ 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):

$$\Delta kWh_{\text{heat}} = (((CFM50_{\text{Exist}} - CFM50_{\text{New}}) / N_{\text{heat}}) * 60 * 24 * HDD * 0.018) / 1,000,000 / \eta_{\text{Heat}} * 293.1$$

Where:

N-heat = conversion from CFM_{50} to CFM_{Natural}
= Based on location and number of stories⁴⁶⁷:

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 location⁴⁶⁸

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

*η*Heat = Efficiency in COP of Heating equipment

⁴⁶⁷ 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".

⁴⁶⁸ 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.



= actual. If not available, use⁴⁶⁹:

System Type	Age of Equipment	HSPF Estimate	COP Estimate ⁴⁷⁰
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.

$$\begin{aligned}\Delta \text{kWh}_{\text{heat}} &= [(((3,400 - 2,250) / 24.5) * 60 * 24 * 3,275 * 0.018) / \\ &\quad 1,000,000 / 2.5] * 293.1 \\ &= 467.1 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW}_{\text{cool}} = \Delta \text{kWh} / \text{FLH}_{\text{cool}} * \text{CF}$$

Where:

FLH_{cool} = Full Load Cooling Hours

= Dependent on location as below:

Location	FLH _{cool}
Wilmington, DE	524 ⁴⁷¹

⁴⁶⁹ These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate.

⁴⁷⁰ To convert HSPF to COP, divide the HSPF rating by 3.413.

⁴⁷¹ 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)



<i>Baltimore, MD</i>	<i>542⁴⁷²</i>
<i>Washington, DC</i>	<i>681</i>

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

= 0.69⁴⁷³

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

= 0.66⁴⁷⁴

Illustrative example – do not use as default assumption

A single story home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta kW = 62.1 / 524 * 0.69$$

$$= 0.08 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

$$\Delta \text{MMBTU} = (((\text{CFM}_{50\text{Exist}} - \text{CFM}_{50\text{New}}) / \text{N-heat}) * 60 * 24 * \text{HDD} * 0.018) / 1,000,000 / \eta_{\text{Heat}}$$

Where:

N-heat = conversion from CFM_{50} to $\text{CFM}_{\text{Natural}}$

= Based on location and number of stories⁴⁷⁵:

⁴⁷² 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.

⁴⁷³ 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.

⁴⁷⁴ 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.

⁴⁷⁵ 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



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 location⁴⁷⁶

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

η_{Heat} = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)
= actual⁴⁷⁷. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%⁴⁷⁸.

speeds and outdoor temperatures provided by the NRDC 30-year climate normals. For more information, see Bruce Harley, CLEAResult "Infiltration Factor Calculations Methodology.doc".

⁴⁷⁶ 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.

⁴⁷⁷ 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.

⁴⁷⁸ 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.



Illustrative example – do not use as default assumption

A single story home in Wilmington, DE with a 70% heating system efficiency, has pre and post blower door test results of 3,400 and 2,250.

$$\begin{aligned}\Delta\text{MMBtu} &= (((3,400 - 2,250) / 24.5) * 60 * 24 * 3,275 * 0.018) / \\ &1,000,000 / 0.7 \\ &= 5.7 \text{ MMBtu}\end{aligned}$$

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 yrs⁴⁷⁹.

Operation and Maintenance Impacts

n/a

⁴⁷⁹ 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 insulation⁴⁸⁰. 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

Savings from reduction in Air Conditioning Load:

$$\Delta kWh = ((1/R_{exist} - 1/R_{new}) * CDH * DUA * Area) / 1,000 / \eta_{Cool} * Adj_{cool}$$

⁴⁸⁰ 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:

R_{exist} = R-value of roof assembly plus any existing insulation
= actual (minimum of R-5)

R_{new} = R-value of roof assembly plus new insulation
= actual

CDH = Cooling Degree Hours⁴⁸¹
= 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 Adjustment⁴⁸²
= 0.75

Area = square footage of area covered by new insulation
= actual

η_{Cool} = Efficiency in SEER of Air Conditioning equipment
= actual. If not available, use⁴⁸³:

Age of Equipment	SEER Estimate
Before 2006	10
After 2006	13

Adj_{cool} = 0.8⁴⁸⁴

Illustrative example – do not use as default assumption

⁴⁸¹ 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/>)

⁴⁸² 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.

⁴⁸³ 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.

⁴⁸⁴ 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.

$$\Delta \text{kWh} = ((1/5 - 1/30) * 9,616 * 0.75 * 1,200) / 1,000 / 12 * 0.8$$

$$= 96 \text{ kWh}$$

Savings for homes with electric heat (Heat Pump or resistance):

$$\Delta \text{kWh} = (((1/\text{Rexist} - 1/\text{Rnew}) * \text{HDD} * 24 * \text{Area}) / 1,000,000 / \eta_{\text{Heat}}) * 293.1 * \text{Adjheat}$$

HDD = Heating Degree Days
= dependent on location⁴⁸⁵

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

1,000,000 = Converts Btu to MMBtu
η_{Heat} = Efficiency in COP of Heating equipment
= actual. If not available, use⁴⁸⁶:

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

⁴⁸⁵ 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.

⁴⁸⁶ 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.



$$\text{Adjheat} = 0.6^{487}$$

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.

$$\begin{aligned}\Delta\text{kWh} &= (((1/5 - 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 2.5) * 293.1 * 0.6 \\ &= 1,167 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta\text{kW} = \Delta\text{kWh} / \text{FLHcool} * \text{CF}$$

Where:

FLHcool

= Full Load Cooling Hours

= Dependent on location as below:

Location	FLHcool
Wilmington, DE	524 ⁴⁸⁸
Baltimore, MD	542 ⁴⁸⁹
Washington, DC	681

CF_{SSP}

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

= 0.69⁴⁹⁰

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

= 0.66⁴⁹¹

⁴⁸⁷ From Illinois TRM, 9 as demonstrated in two years of metering evaluation by Opinion Dynamics

⁴⁸⁸ 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)

⁴⁸⁹ 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.

⁴⁹⁰ 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

$$\Delta \text{MMBTU} = ((1/R_{\text{exist}} - 1/R_{\text{new}}) * \text{HDD} * 24 * \text{Area}) / 1,000,000 / \eta_{\text{Heat}} * \text{Adj}_{\text{heat}}$$

Where:

HDD = Heating Degree Days
= dependent on location⁴⁹²

Location	Heating Degree Days (60°F set point)
Wilmington, DE	3,275
Baltimore, MD	3,457
Washington, DC	2,957

η_{Heat} = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)
= actual⁴⁹³. If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%⁴⁹⁴.

⁴⁹¹ 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.

⁴⁹² 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.

⁴⁹³ 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.



$$\text{Adjheat} = 0.60^{495}$$

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.

$$\begin{aligned}\Delta\text{MMBtu} &= ((1/5 - 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 0.75 * .60 \\ &= 13 \text{ MMBtu}\end{aligned}$$

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 years⁴⁹⁶.

Operation and Maintenance Impacts

n/a

⁴⁹⁴ 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.

⁴⁹⁵ 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.

⁴⁹⁶ 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 ⁴⁹⁷

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

$$\Delta kW_{cooling} = \Delta kW_{REM} * CF$$

⁴⁹⁷ 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:

ΔkW_{REM} = Delta kW calculated in REMRate model
= 0.12 kW per 100 square feet window area

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69⁴⁹⁸

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
= 0.66⁴⁹⁹

$$\Delta kW_{SSP \text{ cooling}} = 0.12 * 0.69$$
$$= 0.083 \text{ kW per 100 square feet of windows}$$

$$\Delta kW_{PJM \text{ cooling}} = 0.12 * 0.66$$
$$= 0.079 \text{ kW per 100 square feet of windows}$$

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.⁵⁰⁰

Measure Life

The measure life is assumed to be 25 years.⁵⁰¹

⁴⁹⁸ 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.

⁴⁹⁹ 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.

⁵⁰⁰ \$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.



Operation and Maintenance Impacts

n/a

⁵⁰¹ 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>.



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 Algorithm⁵⁰²

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

Where:

$$\begin{aligned} \text{kWh}_{\text{cooling}} &= \text{reduction in cooling requirement. Only applicable to homes with central cooling} \\ &= ((1 / R_{\text{Old_AG}} - 1 / (R_{\text{Old_AG}} + R_{\text{Added_AG}})) * \\ &\quad L_{\text{Basement_Wall}} * H_{\text{Basement_Wall_AG}} * (1 - \text{Framing_Factor}) \\ &\quad * CDH * DUA) / (1000 * \eta_{\text{Cool}}) * \text{Adj}_{\text{Basementcool}} \end{aligned}$$

Where:

$$\begin{aligned} R_{\text{Old_AG}} &= R_{\text{Value of foundation wall above grade}} \\ &= \text{Actual, if unknown assume } 1.0^{503} \end{aligned}$$

⁵⁰² 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

⁵⁰³ 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 insulation⁵⁰⁴
 24 = converts days to hours
CDH = Cooling Degree Hours⁵⁰⁵
 = 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.
 = 0.75⁵⁰⁶
η_{Cool} = Efficiency in SEER of Cooling Equipment.
 = Actual. If unknown use⁵⁰⁷:

Age of Equipment	SEER Estimate
Before 2006	10
After 2006	13

⁵⁰⁴ ASHRAE, 2001, "Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP)," Table 7.1

⁵⁰⁵ 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/>)

⁵⁰⁶ 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.

⁵⁰⁷ 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
 $= 80\%^{508}$
 $kWh_{heating}$ = Reduction in annual heating requirement, if electric heat (resistance or heat pump)
 $= (kWh_{AG} + kWh_{BG}) * Adj_{Basement}$

Where:

kWh_{AG} = Savings from insulation on walls or crawlspaces above grade
 $= ((1/R_{Old_AG} - 1/(R_{Old_AG} + R_{Added})) * L_{Basement_Wall} * H_{Basement_Wall_AG} * (1 - Framing_Factor) * HDD * 24) / (3412 * \eta_{Heat})$
 kWh_{BG} = Savings from insulation on walls or crawlspaces below grade
 $= ((1/R_{Old_BG} - 1/(R_{Old_BG} + R_{Added})) * L_{Basement_Wall} * H_{Basement_Wall_BG} * (1 - Framing_Factor) * HDD * 24) / (3412 * \eta_{Heat})$

Where:

HDD = Heating Degree Days
= Dependent on location.⁵⁰⁹

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
 η_{Heat} = Efficiency of Heating system, in COP. If not available, use⁵¹⁰:

⁵⁰⁸ As determined by Illinois Technical Resource Manual

⁵⁰⁹ 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.



<i>System Type</i>	<i>Age of Equipment</i>	<i>HSPF Estimate</i>	<i>COP Estimate</i>
<i>Heat Pump</i>	<i>Before 2006</i>	<i>6.8</i>	<i>2.00</i>
	<i>After 2006</i>	<i>7.7</i>	<i>2.26</i>
<i>Resistance</i>	<i>n/a</i>	<i>n/a</i>	<i>1.00</i>

R_Old_BG = *R-Value of Wall below Grade*
= *Dependent on depth of foundation*⁵¹¹

<i>Depth below grade (ft)</i>	<i>0</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>
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%*⁵¹²

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*

⁵¹⁰ 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

⁵¹¹ Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

⁵¹² As determined by the Illinois Technical Resource Manual.



Dependent on location as below:

<i>Location</i>	<i>Run Hours</i>
<i>Wilmington, DE</i>	<i>524⁵¹³</i>
<i>Baltimore, MD</i>	<i>542⁵¹⁴</i>
<i>Washington, DC</i>	<i>681</i>

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:

<i>Location</i>	<i>FLHheat</i>
<i>Wilmington, DE</i>	<i>935⁵¹⁵</i>
<i>Baltimore, MD</i>	<i>866⁵¹⁶</i>
<i>Washington, DC</i>	<i>822</i>

HSPF = Heating Seasonal Performance Factor of heating equipment
= Actual

⁵¹³ 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)

⁵¹⁴ 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.



Illustrative examples – do not use as default assumption

A single family home in Wilmington is getting its crawlspace insulated with R-13 spray foam and encapsulated. The crawlspace currently has an R-value of 2.25, and a significant portion of the home’s ductwork runs through the crawlspace. The house has a 20x25 footprint, and the crawl space walls are 7 feet tall, 3 of which are above grade. The HVAC unit is a heat pump with 13 SEER and 2.26 COP.

$$\begin{aligned}\Delta \text{kWh} &= \text{kWh}_{\text{cooling}} + \text{kWh}_{\text{heating}} + \text{kWh}_{\text{ducts}} \\ \text{kWh}_{\text{cooling}} &= ((1/2.25 - 1/(2.25 + 13)) * (20*2 + 25*2) * 3 * (1-0) * 7514 * 0.75) / (1,000 * 13) * 0.8 \\ &= 35 \text{ kWh} \\ \text{kWh}_{\text{heating}} &= (((1/2.25 - 1/(2.25 + 13)) * (20*2 + 25*2) * 3 * (1-0) * 3275 * 24) / (3412 * 2.26)) + [((1/(6.42 + 2.25) - 1/(6.42 + 2.25 + 13)) * (20*2 + 25*2) * 4 * (1-0) * 3275 * 24) / (3412 * 2.26)] * 0.6 \\ &= 722 \text{ kWh} \\ \text{kWh}_{\text{ducts}} &= 524 * 36,000 * (1/13) * 0.05 / 1000 + 935 * 36,000 * (1/8) * 0.05 / 1,000 \\ &= 283 \text{ kWh} \\ \Delta \text{kWh} &= 35 + 722 + 283 \\ &= 1,040 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \text{kWh}_{\text{cooling}} / \text{Hours_Cool} * \text{CF}$$

Where:

$$\begin{aligned}CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)} \\ &= 0.69^{517} \\ CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather} \\ &= 0.66^{518}\end{aligned}$$

⁵¹⁷ 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 examples – do not use as default assumption

For the house described above:

$$\begin{aligned}\Delta kW &= 35 / 524 * 0.69 \\ &= 0.046 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

If Natural Gas heating:

$$\Delta \text{therms} = (\text{therms}_{AG} + \text{therms}_{BG}) * Adj_{Basement} + \text{therms}_{duct}$$

Where:

$$\begin{aligned}\text{therms}_{AG} &= \text{Savings from insulation on walls or crawlspaces above grade} \\ &= ((1/R_{Old_AG} - 1/(R_{Old_AG} + R_{Added})) * \\ &\quad L_{Basement_Wall} * H_{Basement_Wall_AG} * (1 - \\ &\quad \text{Framing_Factor}) * HDD * 24) / (100,067 * \eta_{Heat}) \\ \text{therms}_{BG} &= \text{Savings from insulation on walls or crawlspaces below grade} \\ &= ((1/R_{Old_BG} - 1/(R_{Old_BG} + R_{Added})) * \\ &\quad L_{Basement_Wall} * H_{Basement_Wall_BG} * (1 - \\ &\quad \text{Framing_Factor}) * HDD * 24) / (100,067 * \eta_{Heat}) \\ \text{therms}_{duct} &= \text{Hours}_{Heat} * \text{Btu/Hour} * \text{AFUE} * \text{Duct_Factor} / 100,000\end{aligned}$$

Where:

$$\text{Hours}_{heat} = \text{Equivalent Full Load Heating Hours}$$

Location	EFLH
Wilmington, DE	848 ⁵¹⁹
Baltimore, MD	620 ⁵²⁰
Washington, DC	528 ⁵²¹

⁵¹⁸ 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.

⁵¹⁹ 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

⁵²⁰ 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.



η_{Heat} = Efficiency of Heating equipment (equipment efficiency * distribution efficiency)
= actual⁵²². If not available, use 84% for equipment efficiency and 78% for distribution efficiency to give 66%⁵²³.

Other factors as defined above

Illustrative examples – do not use as default assumption

For the house described above, but with a central furnace:

$\Delta therm_{AG}$ = $(therm_{AG} + therm_{BG}) * Adj_{Basement} + therm_{duct}$
= $((1/2.25 - 1/(2.25+13)) * (20*2+25*2) * 3 * (1-0) * 3275 * 24) / (100,067 * 0.66)$
= 122 therms
 $therm_{BG}$ = $((1/(2.25+6.42) - 1/(2.25+6.42+13)) * (20*2+25*2) * 4 * (1-0) * 3275 * 24) / (100,067 * 0.66)$
= 30 therms
 $therm_{duct}$ = $848 * 100,000 * .84 * 0.05 / 100,000$
= 36 therms
 $\Delta therm_{AG}$ = $(122 + 30) * 0.6 + 36$
= 127

Annual Water Savings Algorithm

n/a

⁵²¹ 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.

⁵²² 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.

⁵²³ 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.



Incremental Cost

The incremental cost for this retrofit measure should be the actual installation and labor cost to perform the insulation work.

Measure Life

The expected measure life is assumed to be 25 years.⁵²⁴

Operation and Maintenance Impacts

n/a

⁵²⁴ 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>.



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

$$\Delta kWh = kWh_{Base} - kWh_{Two Speed}^{525}$$

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

$$\begin{aligned}\Delta kWh &= 707 - 177 \\ &= 530 \text{ kWh}\end{aligned}$$

⁵²⁵ 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

$$\Delta kW = (kW_{Base} - kW_{Two Speed}) * CF^{526}$$

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)

= 0.20⁵²⁷

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

= 0.27⁵²⁸

$$\Delta kW_{SSP} = (1.3 - 0.171) * 0.20$$

= 0.23 kW

$$\Delta kW_{SSP} = (1.3 - 0.171) * 0.27$$

= 0.31 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

⁵²⁶ 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

⁵²⁷ Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

⁵²⁸ Ibid.



The incremental cost for this time of sale measure is assumed to be \$175 for a two speed pool pump motor⁵²⁹.

Measure Life

The measure life is assumed to be 10 yrs⁵³⁰.

Operation and Maintenance Impacts

n/a

⁵²⁹ Based on review of Lockheed Martin pump retail price data, July 2009.

⁵³⁰ 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

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}^{531}$$

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

$$\Delta kWh = 707 - 113$$

⁵³¹ 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



$$= 594 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{\text{Base}} - kW_{\text{Two Speed}}) * CF^{532}$$

Where:

kW_{Base} = Connected load of baseline motor

$$= 1.3 \text{ kW}$$

$kW_{\text{Two Speed}}$ = Connected load of variable speed motor

$$= 0.087 \text{ kW}$$

CF_{SSP} = Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)

$$= 0.20^{533}$$

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

$$= 0.27^{534}$$

$$\Delta kW_{SSP} = (1.3 - 0.087) * 0.20$$

$$= 0.24 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3 - 0.087) * 0.27$$

$$= 0.34 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

⁵³² 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

⁵³³ Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

⁵³⁴ Ibid.



Incremental Cost

The incremental cost for this time of sale measure is assumed to be \$549 for a variable speed pool pump motor⁵³⁵.

Measure Life

The measure life is assumed to be 10 yrs⁵³⁶.

Operation and Maintenance Impacts

n/a

⁵³⁵ 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.

⁵³⁶ 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

$$\Delta \text{kWh} = (\text{kWh}_{\text{office}} * \text{Weighting}_{\text{Office}} + \text{kWh}_{\text{Ent}} * \text{Weighting}_{\text{Ent}}) * \text{ISR}$$

Where:

$\text{kWh}_{\text{office}}$ = Estimated energy savings from using an APS in a home office



$$= 31.0 \text{ kWh}^{537}$$

Weighting_{Office} = Relative penetration of computers

$$= 41\%^{538}$$

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system

$$= 75.1 \text{ kWh}^{539}$$

Weighting_{Ent} = Relative penetration of televisions

$$= 59\%^{540}$$

ISR = In service rate

$$= 89\%^{541}$$

$$\Delta \text{kWh} = (31 * 41\% + 75.1 * 59\%) * 89\%$$

$$= 50.7 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

⁵³⁷ NYSERDA 2011, Advanced Power Strip Research Report, <http://www.nyseda.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.

⁵³⁸ EmPower 2012 Residential Retrofit evaluation

⁵³⁹ NYSERDA 2011, Advanced Power Strip Research Report

⁵⁴⁰ EmPower 2012 Residential Retrofit evaluation

⁵⁴¹ EmPower EY6 QHEC Survey data.



$$\begin{aligned} \text{Hours} &= \text{Annual hours when controlled standby loads are turned off} \\ &= 6,351^{542} \\ CF &= \text{Coincidence Factor} \\ &= 0.8^{543} \end{aligned}$$

$$\begin{aligned} \Delta kW &= (50.7/6,351) * 0.8 \\ &= 0.0064 \text{ kW} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be \$18⁵⁴⁴.

Measure Life

The measure life is assumed to be 4 years⁵⁴⁵.

Operation and Maintenance Impacts

n/a

⁵⁴² EmPower 2012 Residential Retrofit evaluation

⁵⁴³ Ibid

⁵⁴⁴ IILSAG 2015 Analysis

⁵⁴⁵ 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.



Retail Products Platform

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 3.0.⁵⁴⁶ 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% andn 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 ammount.

Annual Energy Savings Algorithm⁵⁴⁷

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:

$$\begin{aligned} kWh_{base} &= \text{Baseline unit energy consumption} \\ &= \text{Assumed to be 69 kWh/year}^{548} \\ kWh_{eff} &= \text{Efficient unit energy consumption} \end{aligned}$$

⁵⁴⁶<http://www.energystar.gov/sites/default/files/Final%20Version%203.0%20AV%20Program%20Requirements%20%28Rev%20Dec-2014%29.pdf>

⁵⁴⁷ Energy Savings from this measure are derived from Energy Star estimates. See 'RPP Product Analysis 9-23-15.xlsx'

⁵⁴⁸ 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>.



= Assumed to be 25 kWh/year⁵⁴⁹ for the ENERGY STAR +50% Tier and 42.5 kWh/ year for the ENERGY STAR +15% Tier.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0.0005^{550}$$

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 \$0⁵⁵¹.

Measure Life

The expected measure life is assumed to be 7 years.⁵⁵²

Operation and Maintenance Impacts

n/a

⁵⁴⁹ 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.

⁵⁵⁰ Wattage difference between base and efficient sound bars when in sleep mode

⁵⁵¹ Incremental cost comes from Energy Star characterization. See 'RPP Product Analysis 9-23-15.xlsx'

⁵⁵² ENERGY STAR assumes a 7-year useful life.



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 $1.73 \times \text{Total Volume}$).⁵⁵³

Product Category	Federal Baseline Maximum Energy Usage in kWh/year ⁵⁵⁴	ENERGY STAR Maximum Energy Usage in kWh/year ⁵⁵⁵
Upright Freezers	$8.62 \times \text{AV} + 228.3$	$7.76 \times \text{AV} + 205.5$
Chest Freezers	$7.29 \times \text{AV} + 107.8$	$6.56 \times \text{AV} + 97.0$

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

⁵⁵³ http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746

⁵⁵⁴ https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

⁵⁵⁵

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 ⁵⁵⁶	Adj. Volume Use	kWh_{BASE}	kWh_{ESTAR}	$kWh_{ESTAR} + 5\%$	$kWh - Estar$	$kWh - Estar + 5\%$	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 values⁵⁵⁷.

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor

= 1.23⁵⁵⁸

⁵⁵⁶ Savings values come from Energy Star Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

⁵⁵⁷ 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.

⁵⁵⁸ 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



LSAF = Load Shape Adjustment Factor
= 1.15⁵⁵⁹

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 freezer⁵⁶⁰.

Measure Life

The measure life is assumed to be 11 years⁵⁶¹.

Operation and Maintenance Impacts

n/a

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.

⁵⁵⁹ 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).

⁵⁶⁰ 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>

⁵⁶¹ ENERGY STAR assumes 11 years based on Appliance Magazine U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture for 2005-2012, 2011.



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 dryers⁵⁶². 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

$$\Delta \text{kWh}^{563} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}$$

⁵⁶² 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

⁵⁶³ 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



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 ⁵⁶⁴	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 = $\Delta kWh / \text{Hours} * CF$

Where:

ΔkWh = Energy Savings as calculated above

Hours = Annual run hours of clothes dryer.
= 290 hours per year.⁵⁶⁵

requiring an updated DOE test, published in Appendix D2. On average, clothes dryers use more energy when tested under Appendix D2, and so the translation adjusts the D1 Federal standard to reflect the estimated average energy efficiency performance of minimally-compliant 2015 models under D2. The translation values (-16.6% for the electric standard and -13.9% for the gas dryers) are based on DOE testing published in their NOPR test procedure in January 2013. Performance requirements for ENERGY STAR certified clothes dryers can be found in the ENERGY STAR specifications (V 1.0) (available at: <http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%201%200%20Clothes%20Dryers%20Program%20Requirements.pdf>). Calculations assume 283 cycles per year and an 8.45 lb load for standard sized dryers (≥ 4.4 cu-ft capacity).

⁵⁶⁴ Savings values come from Energy Star Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

⁵⁶⁵ Assumes average of 56 minutes per cycle based on Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014



$$CF = \text{Summer Peak Coincidence Factor for measure}$$
$$= 2.9\%^{566}$$

Annual Fossil Fuel Savings Algorithm

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

$$\Delta \text{MMBtu} = \text{MMBtu}_{\text{Base}} - \text{MMBtu}_{\text{STAR}}$$

Where:

$\text{MMBtu}_{\text{BASE}}$ = Baseline MMBtu consumption per year
= As presented in the table below

$\text{MMBtu}_{\text{ESTAR}}$ = ENERGY STAR MMBtu consumption per year
= As presented in the table below

Product Category ⁵⁶⁷	$\text{MMBtu}_{\text{BASE}}$	$\text{MMBtu}_{\text{ESTAR}}$	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 \$75.⁵⁶⁸

Measure Life

The expected measure life is assumed to be 12 years⁵⁶⁹.

⁵⁶⁶ 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.

⁵⁶⁷ Savings values come from Energy Star Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

⁵⁶⁸ Energy Star Appliance Calculator, which cites "Cadmus Research on available models, July 2016."

⁵⁶⁹ 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.



REGIONAL EVALUATION,
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Operation and Maintenance Impacts

n/a



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 below⁵⁷⁰.

- 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

$$\Delta \text{kWh}^{571} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}$$

Where:

⁵⁷⁰ http://www.energystar.gov/sites/default/files/specs//private/Room_Air_Cleaners_Final_V1.2_Specification.pdf

⁵⁷¹ 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

ΔkW = $\Delta kWh / \text{Hours} * CF$

Where:

ΔkWh = Gross customer annual kWh savings for the measure
Hours = Average hours of use per year
= 5840 hours⁵⁷²
CF = Summer Peak Coincidence Factor for measure
= 0.67⁵⁷³

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 \$0.⁵⁷⁴

Measure Life

⁵⁷² Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

⁵⁷³ Assumes appliance use is equally likely at any hour of the day or night.

⁵⁷⁴ ENERGY STAR Appliance Savings Calculator, which cites "EPA research on available models, 2012"



The measure life is assumed to be 9 years⁵⁷⁵.

Operation and Maintenance Impacts

There are no operation and maintenance cost adjustments for this measure.⁵⁷⁶

⁵⁷⁵ ENERGY STAR assumption based on Lawrence Berkeley National Laboratory 2008 Status Report: Savings Estimates for the ENERGY STAR Voluntary Labeling Program, available at: [http://enduse.lbl.gov/Info/LBNL-56380\(2008\).pdf](http://enduse.lbl.gov/Info/LBNL-56380(2008).pdf)

⁵⁷⁶ 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.



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.⁵⁷⁷

⁵⁷⁷ 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.⁵⁷⁸

Annual Energy Savings Algorithm

$$\Delta \text{kWh}^{579} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}$$

Where:

kWh_{BASE} = Baseline kWh consumption per year
= see table below for calculated values

$\text{kWh}_{\text{ESTAR}}$ = ENERGY STAR kWh consumption per year
= see table below for calculated values

Location	Full-Load Cooling Hours	Savings (kWh/year)
Wilmington, DE	1,015	74.72
Baltimore, MD	1,050	77.30
Washington, DC	1,320	97.18

Summer Coincident Peak kW Savings Algorithm

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

Where:

CF = Summer Peak Coincidence Factor for measure

⁵⁷⁸

<http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%204.0%20Room%20Air%20Conditioners%20Program%20Requirements.pdf>

⁵⁷⁹ 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'



CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.31⁵⁸⁰

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
= 0.3⁵⁸¹

Using deemed values above:

$$\begin{aligned}\Delta kW_{\text{ENERGY STAR SSP}} &= (8500 * (1/10.9 - 1/11.3)) / 1000 * 0.31 \\ &= 0.009 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{CEE TIER 1 SSP}} &= (8500 * (1/10.9 - 1/11.8)) / 1000 * 0.31 \\ &= 0.018 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{ENERGY STAR PJM}} &= (8500 * (1/10.9 - 1/11.3)) / 1000 * 0.30 \\ &= 0.008 \text{ kW}\end{aligned}$$

$$\begin{aligned}\Delta kW_{\text{CEE TIER 1 PJM}} &= (8500 * (1/10.9 - 1/11.8)) / 1000 * 0.30 \\ &= 0.018 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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

⁵⁸⁰ Calculated by multiplying the ratio of SSP:PJM for the Central AC measure (0.69:0.66) to the assumption for PJM.

⁵⁸¹ 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).



Measure Life

The measure life is assumed to be 9 years.⁵⁸²

Operation and Maintenance Impacts

n/a

⁵⁸² Based on Appliances Magazine – Market Research - The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013 (Dec. 2013).



COMMERCIAL & INDUSTRIAL MARKET SECTOR

Lighting End Use

LED Exit Sign

Unique Measure Code(s): CI_LT_EREP_LEDEXI_0614

Effective Date: June 2014

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

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR} * \text{WHFe}$$

Where:

WattsBASE = Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.⁵⁸³

WattsEE = Actual Connected load of LED exit sign

HOURS = Average hours of use per year
= 8,760⁵⁸⁴

⁵⁸³ Assumes a fluorescent illuminated exit sign. Wattage consistent with ENERGY STAR assumptions. See http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheets.pdf.

⁵⁸⁴ Assumes operation 24 hours per day, 365 days per year.



<i>ISR</i>	<i>= In Service Rate or percentage of units rebated that get installed</i> <i>= 1.00⁵⁸⁵</i>
<i>WHFe</i>	<i>= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.</i> <i>= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.</i>

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\text{WattsBASE} - \text{WattsEE}) / 1000 * \text{ISR} * \text{WHFd} * \text{CF}$$

Where:

<i>WHFd</i>	<i>= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.</i> <i>= 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 D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.</i>
<i>CF</i>	<i>= Summer Peak Coincidence Factor for measure</i> <i>= 1.0⁵⁸⁶</i>

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\begin{aligned} \Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= -\Delta \text{kWh} * 0.00065 \end{aligned}$$

Where:

<i>0.7</i>	<i>= Aspect ratio⁵⁸⁷</i>
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⁵⁸⁵ 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.

⁵⁸⁶ Efficiency Vermont Technical Reference Manual 2009-55, December 2008.



0.003413 = Constant to convert kWh to MMBTU
 0.23 = Fraction of lighting heat that contributes to space heating ⁵⁸⁸
 0.75 = Assumed heating system efficiency ⁵⁸⁹

Annual Water Savings Algorithm

n/a

Incremental Cost

The lifecycle NPV incremental cost for this retrofit measure is \$35.⁵⁹⁰

Measure Life

The measure life is assumed to be 16 years.⁵⁹¹

Operation and Maintenance Impacts

	Baseline
	CFL
Replacement Cost	\$12 ⁵⁹²
Component Life (years)	1.14 ⁵⁹³

⁵⁸⁷ 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.

⁵⁸⁸ 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).

⁵⁸⁹ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁵⁹⁰ 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. (RSMMeans Electrical Cost Data 2008), the total installed cost would be approximately \$35.

⁵⁹¹ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008

⁵⁹² Represents the full installed cost of a replacement fluorescent lamp. Replacement lamps can typically be purchased for ~\$5 (based on a review of online retailers performed 3/14/2013 including "<http://www.exitlightco.com/>" and "<http://www.1000bulbs.com/>"). Assuming lamp replacement requires 15 minutes of a common building laborer's time in Washington D.C. (RSMMeans Electrical Cost Data 2008), the total installed cost would be approximately \$12.

⁵⁹³ Assumes rated life of fluorescent replacement lamp is 10,000 hours. Assuming annual exit sign operating hours of 8,760, estimated lamp life is 1.14 years.



The calculated net present value of the baseline replacement costs are presented below⁵⁹⁴:

Baseline	NPV of Baseline Replacement Costs
	2017
CFL	\$108

⁵⁹⁴ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.



Solid State Lighting (LED) Recessed Downlight Luminaire

Unique Measure Code: CI_LT_TOS_SSLEDWN_0615

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 (i.e. time of sale). The SSL downlight should meet the ENERGY STAR Luminaires Version 2.0 specification⁵⁹⁵. 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

$$\Delta \text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1,000) * \text{ISR} * \text{HOURS} * \text{WHFe}$$

Where:

WattsBase = Connected load of baseline lamp

⁵⁹⁵ 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 below⁵⁹⁶; if unknown assume 65W⁵⁹⁷

Lower Lumen Range	Upper Lumen Range	WattsBase	Baseline Shift ≥ 90 CRI	Baseline Shift < 90 CRI
400	449	40	7%	10%
450	499	45	7%	10%
500	649	50	9%	12%
650	1419	65	13%	16%

WattsEE = Connected load of efficient lamp
= Actual. If unknown assume 9.2W⁵⁹⁸

ISR = In Service Rate or percentage of units rebated that get installed.
= 1.0⁵⁹⁹

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.⁶⁰⁰

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

⁵⁹⁶ Based on ENERGY STAR equivalence table;

http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumens

⁵⁹⁷ 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.

⁵⁹⁸ Calculated using the minimum lumen output for a BR lamp of 650 lumens and the 60 lumens per watt specified by ENERGY STAR v2.0.

⁵⁹⁹ 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.

⁶⁰⁰ 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.



*HVAC type is unknown or the space is unconditioned,
assume WHFe = WHFd = 1.0.*

Summer Coincident Peak kW Savings Algorithm

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

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.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\begin{aligned} \Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= (-\Delta \text{kWh} / \text{WHFe}) * 0.00073 \end{aligned}$$

Where:

- 0.7** = Aspect ratio ⁶⁰¹
- 0.003413** = Constant to convert kWh to MMBTU
- 0.23** = Fraction of lighting heat that contributes to space heating ⁶⁰²
- 0.75** = Assumed heating system efficiency ⁶⁰³

⁶⁰¹ 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.

⁶⁰² 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).

⁶⁰³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Annual Water Savings Algorithm

n/a

Baseline Adjustment

To account for new EISA standards taking effect in 2020, the savings for this measure should be reduced to account for the higher baselines. The “WattsBase” table above shows the calculated adjustments based on luminaire CRI. The calculated energy savings for the applicable lamp should be multiplied by the appropriate factor from the table for years 2020 and beyond⁶⁰⁴.

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 sale⁶⁰⁵. 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

The measure life is assumed to be 14.2 years for downlights featuring inseparable components and 7.1 years for downlights with replaceable parts⁶⁰⁶.

⁶⁰⁴ See ‘ESTAR Integrated Screw SSL Lamp_032014.xls’ for details. The Minimum Lamp Efficacy Requirements in ENERGY STAR Product Specification for Lamps (Light Bulbs) V2.0 vary by Color Rendering Index (CRI).

⁶⁰⁵ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

⁶⁰⁶ The ENERGY STAR specification for solid state recessed downlights requires luminaires using LED lamps to maintain $\geq 70\%$ initial light output for 25,000 hours in an indoor application for separable luminaires and 50,000 for inseparable luminaires. Measure life is therefore assumed to be 14.2 years for downlights featuring inseparable components (calculated as 50,000 hours divided by an approximate 3,500 annual operating hours) and 7.1 years for downlights with replaceable parts (25,000/3,500).



Operation and Maintenance Impacts

The leveled baseline replacement cost over the lifetime of the SSL is presented below.⁶⁰⁷ 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)	0.57 ⁶⁰⁸

The calculated net present value of the baseline replacement costs is \$210 for downlights featuring inseparable components and \$118 for downlights with replaceable parts⁶⁰⁹.

⁶⁰⁷ Costs are from Itron, Mid-Atlantic TRM Version 7.0 Incremental Costs Update, 2017. Component costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

⁶⁰⁸ 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.

⁶⁰⁹ 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_0614

Effective Date: June 2014

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

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{WHFe}$$

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.⁶¹⁰

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

⁶¹⁰ 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.



unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{WHFd} * \text{CF}$$

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.

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\begin{aligned} \Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= -\Delta \text{kWh} * 0.00065 \end{aligned}$$

Where:

- 0.7** = Aspect ratio ⁶¹¹
- 0.003413** = Constant to convert kWh to MMBTU
- 0.23** = Fraction of lighting heat that contributes to space heating ⁶¹²
- 0.75** = Assumed heating system efficiency ⁶¹³

⁶¹¹ 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.

⁶¹² 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.⁶¹⁴

Measure Life

The measure life is assumed to be 15 years.⁶¹⁵

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 \$3.61 per lamp⁶¹⁶.

⁶¹³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁶¹⁴ 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.

⁶¹⁵ 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>

⁶¹⁶ 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_0614, CI_LT_RF_OSFIX/REM_0614

Effective Date: June 2014

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

$$\Delta \text{kWh} = \text{kW}_{\text{connected}} * \text{HOURS} * \text{SVGe} * \text{ISR} * \text{WHFe}$$

Where:

kW_{connected} = Assumed kW lighting load connected to control.

HOURS = Average hours of use per year.

= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.

Otherwise, use site specific annual operating hours information.⁶¹⁷

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

= 0.28⁶¹⁸

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

⁶¹⁷ 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.

⁶¹⁸ 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.



$= 1.00$ ⁶¹⁹

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.

Summer Coincident Peak kW Savings Algorithm

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

Where:

SVGd = Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.
 $= 0.14$ ⁶²⁰

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, a 400W connected load being controlled in a conditioned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

⁶¹⁹ 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.

⁶²⁰ 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.



$$\begin{aligned}\Delta kW &= 0.4 * 0.14 * 1.00 * 1.32 * 0.69 \\ &= 0.051 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\begin{aligned}\Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= -\Delta \text{kWh} * 0.00065\end{aligned}$$

Where:

0.7	= Aspect ratio ⁶²¹
0.003413	= Constant to convert kWh to MMBTU
0.23	= Fraction of lighting heat that contributes to space heating ⁶²²
0.75	= Assumed heating system efficiency ⁶²³

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 ultrasonic capabilities. ⁶²⁴

Measure Life

The measure life is assumed to be 10 years. ⁶²⁵

⁶²¹ 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.

⁶²² 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).

⁶²³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁶²⁴ 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/5548/download?token=pLIMjfvz>.



Operation and Maintenance Impacts

n/a

⁶²⁵ 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_0614, CI_LT_RF_DDIM_0614

Effective Date: June 2014

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

$$\Delta \text{kWh} = \text{kW}_{\text{connected}} \times \text{HOURS} \times \text{SVG} \times \text{ISR} \times \text{WHFe}$$

Where:

kW_{connected} = Assumed kW lighting load connected to control.

HOURS = Average hours of use per year

= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.

Otherwise, use site specific annual operating hours information.⁶²⁶

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

= 0.28⁶²⁷

⁶²⁶ 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.



- ISR* = In Service Rate or percentage of units rebated that get installed
= 1.00⁶²⁸
- 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.

Summer Coincident Peak kW Savings Algorithm⁶²⁹

$$\Delta kW = kW_{\text{connected}} \times SVG \times ISR \times WHFd \times CF$$

Where:

- WHFd* = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix 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, a 400W connected load being controlled in a conditioned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

⁶²⁷ 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.

⁶²⁸ 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.

⁶²⁹ 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.



$$\begin{aligned}\Delta kW &= 0.4 * 0.28 * 1.00 * 1.32 * 0.69 \\ &= 0.10 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\begin{aligned}\Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= -\Delta \text{kWh} * 0.00065\end{aligned}$$

Where:

0.7	= Aspect ratio ⁶³⁰
0.003413	= Constant to convert kWh to MMBTU
0.23	= Fraction of lighting heat that contributes to space heating ⁶³¹
0.75	= Assumed heating system efficiency ⁶³²

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.⁶³³

Measure Life

The measure life is assumed to be 10 years.⁶³⁴

⁶³⁰ 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.

⁶³¹ 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).

⁶³² Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁶³³ 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.

⁶³⁴ 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>



Operation and Maintenance Impacts

n/a



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.⁶³⁵

Definition of Efficient Condition

⁶³⁵ 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 Algorithm⁶³⁶

$$\Delta \text{kWh} = ((\text{LPDBASE} - \text{LPDEE}) / 1000) * \text{AREA} * \text{HOURS} * \text{WHFe}$$

Where:

<i>LPDBASE</i>	<i>= Baseline lighting power density for building or space type (W/ft²). See tables below for values by jurisdiction and method.⁶³⁷</i>
<i>LPDEE</i>	<i>= Efficient lighting power density (W/ft²) = Actual calculated</i>
<i>AREA</i>	<i>= Building or space area (ft²)</i>
<i>HOURS</i>	<i>= 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.⁶³⁸</i>
<i>WHFe</i>	<i>= 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.</i>

⁶³⁶ 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.

⁶³⁷ 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).

⁶³⁸ 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 Jurisdiction⁶³⁹

Building Area Type	Lighting Power Density (W/ft ²)	
	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

⁶³⁹ 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.



Building Area Type	Lighting Power Density (W/ft ²)	
	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 Delaware⁶⁴⁰

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

⁶⁴⁰ 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.



Corridor/transition	0.7
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 Maryland⁶⁴¹

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

⁶⁴¹ IECC 2015, Table C405.4.2 (2).



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
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/ft²)
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 ft² conditioned office building with gas heat in in DE using the Building Area Method with an LPDEE of 0.75:

$$\begin{aligned}\Delta \text{kWh} &= ((0.9 - 0.75) / 1000) * 15,000 * 2,969 * 1.10 \\ &= 7,348 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = ((\text{LPDBASE} - \text{LPDEE}) / 1000) * \text{AREA} * \text{WHFd} * \text{CF}$$

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 $\text{WHFe} = \text{WHFd} = 1.0$.
- CF* = Summer Peak Coincidence Factor for measure
= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft² conditioned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75 and estimating PJM summer peak coincidence:

$$\Delta \text{kWh} = ((0.9 - 0.75) / 1000) * 15,000 * 1.32 * 0.69$$



$$= 2.05 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\begin{aligned}\Delta \text{MMBTU} &= (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= (-\Delta \text{kWh} / \text{WHFe}) * 0.00073\end{aligned}$$

Where:

$$\begin{aligned}0.7 &= \text{Aspect ratio}^{642} \\ 0.003413 &= \text{Constant to convert kWh to MMBTU} \\ 0.23 &= \text{Fraction of lighting heat that contributes to space heating}^{643} \\ 0.75 &= \text{Assumed heating system efficiency}^{644}\end{aligned}$$

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft² conditioned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75:

$$\begin{aligned}\Delta \text{kWh} &= (-7,348 / 1.10) * 0.00073 \\ &= -4.88 \text{ MMBtu}\end{aligned}$$

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.

⁶⁴² 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.

⁶⁴³ 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).

⁶⁴⁴ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.



Measure Life

The measure life is assumed to be 15 years.⁶⁴⁵

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of the efficient and baseline replacement components, there may be significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs should be estimated on a case-by-case basis.

⁶⁴⁵ 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.



LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Luminaires and Retrofit Kits

Unique Measure Code(s): CI_LT_TOS_LEDODPO_0615, CI_LT_RF_LEDODPO_0615

Effective Date: June 2015

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 List⁶⁴⁶.

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*

⁶⁴⁶ 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 Wattage⁶⁴⁷

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

⁶⁴⁷ 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 3,338⁶⁴⁸.
Otherwise, use site specific annual operating hours information.⁶⁴⁹*

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\begin{aligned}\Delta \text{kWh} &= ((288 - 172) / 1000) * 3,338 \\ &= 387 \text{ kWh}\end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * CF$$

Where:

*CF = Summer Peak Coincidence Factor for measure
= 0⁶⁵⁰*

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\begin{aligned}\Delta \text{kW} &= ((288 - 172) / 1000) * 0 \\ &= 0 \text{ kW}\end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

⁶⁴⁸ Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

⁶⁴⁹ 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.

⁶⁵⁰ 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.⁶⁵¹

Measure Description	Time of Sale / New	Early Replacement
LED Fixtures up to 150 W	\$218	\$413
LED Fixtures between 150W to 265W	\$740	\$996

Measure Life

The measure life is assumed to be 18 years.⁶⁵²

Operation and Maintenance Impacts⁶⁵³

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

⁶⁵¹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

⁶⁵² The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <<https://www.designlights.org/resources/file/NEEPDLCQPL>> is 50,000 hours for both luminaires and retrofit kits. 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.

⁶⁵³ 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.



measure life is \$70.44 per lamp for time of sale and \$66.85 per lamp for early replacement⁶⁵⁴.

⁶⁵⁴ 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_0615, CI_LT_RF_LEDHB_0615

Effective Date: June 2015

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 List⁶⁵⁵.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR} * \text{WHFe}$$

Where:

WattsBASE = Actual Connected load of baseline fixture
WattsEE = Actual Connected load of the LED fixture
HOURS = Average hours of use per year

⁶⁵⁵ DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>



	<i>= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.</i>
	<i>Otherwise, use site specific annual operating hours information.⁶⁵⁶</i>
ISR	<i>= In Service Rate or percentage of units rebated that get installed</i> <i>= 1.00⁶⁵⁷</i>
WHFe	<i>= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.</i> <i>= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.</i>

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}$$

Where:

WHFd	<i>= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.</i> <i>= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.</i>
CF	<i>= Summer Peak Coincidence Factor for measure</i> <i>= See table “C&I Interior Lighting Coincidence Factors by Building Type” in Appendix D.</i>

⁶⁵⁶ 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.

⁶⁵⁷ 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.

$$\begin{aligned}\Delta\text{MMBTU} &= (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= -\Delta\text{kWh} * 0.00065\end{aligned}$$

Where:

- 1.0 = Aspect ratio ⁶⁵⁸
- 0.003413 = Constant to convert kWh to MMBTU
- 0.23 = Fraction of lighting heat that contributes to space heating ⁶⁵⁹
- 0.75 = Assumed heating system efficiency ⁶⁶⁰

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.⁶⁶¹

Measure Description	Time of Sale	Early Replacement
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⁶⁵⁸ 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.

⁶⁵⁹ 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).

⁶⁶⁰ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁶⁶¹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.



LED High Bay Fixture up to 220W	\$149	\$298
LED High Bay Fixture between 220 - 320W	\$387	\$549
LED High Bay Fixture greater than 320 W	\$1,003	\$1,182

Measure Life

The measure life is assumed to be 12 years for both luminaires and retrofit kits.⁶⁶²

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 \$48.25 per lamp for time of sale and \$49.38 per lamp for early replacement⁶⁶³.

⁶⁶² The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <<https://www.designlights.org/resources/file/NEEPDLCQPL>> is 50,000 hours for both luminaires and retrofit kits. Assuming average annual operating hours of 4,116 for a typical warehouse lighting application, the estimated measure life is 12 years.

⁶⁶³ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.



LED 1x4, 2x2, and 2x4 Luminaires and Retrofit Kits

Unique Measure Code(s): CI_LT_TOS_LED1x4_0615, CI_LT_TOS_LED2x2_0615, CI_LT_TOS_LED2x4_0615, CI_LT_RF_LED1x4_0615, CI_LT_RF_LED2x2_0615, CI_LT_RF_LED2x4_0615

Effective Date: June 2015

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 List⁶⁶⁴.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR} * \text{WHFe}$$

Where:

WattsBASE = Actual Connected load of baseline fixture

WattsEE = Actual Connected load of the LED fixture

⁶⁶⁴ DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>



<i>HOURS</i>	<p>= Average hours of use per year</p> <p>= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.⁶⁶⁵</p> <p>Otherwise, use site specific annual operating hours information.⁶⁶⁶</p>
<i>ISR</i>	<p>= In Service Rate or percentage of units rebated that get installed</p> <p>= 1.00⁶⁶⁷</p>
<i>WHFe</i>	<p>= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.</p> <p>= 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.</p>

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}$$

Where:

<i>WHFd</i>	<p>= Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.</p> <p>= 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.</p>
<i>CF</i>	= Summer Peak Coincidence Factor for measure

⁶⁶⁵ 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.

⁶⁶⁶ 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.

⁶⁶⁷ 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.

$$\begin{aligned}\Delta\text{MMBTU} &= (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= -\Delta\text{kWh} * 0.00065\end{aligned}$$

Where:

$$\begin{aligned}0.7 &= \text{Aspect ratio}^{668} \\ 0.003413 &= \text{Constant to convert kWh to MMBTU} \\ 0.23 &= \text{Fraction of lighting heat that contributes to space heating}^{669} \\ 0.75 &= \text{Assumed heating system efficiency}^{670}\end{aligned}$$

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.⁶⁷¹

⁶⁶⁸ 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.

⁶⁶⁹ 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).

⁶⁷⁰ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁶⁷¹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.



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

The measure life is assumed to be 14 years.⁶⁷²

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 \$1.57 per kilolumen of luminaire initial lumen output for time of sale and \$0.20 per kilolumen of luminaire initial lumen output for early replacement⁶⁷³

⁶⁷² The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <<https://www.designlights.org/resources/file/NEEPDLCQPL>> is 50,000 hours for both luminaires and retrofit kits. Assuming average annual operating hours of 3,500 for a typical commercial lighting application, the estimated measure life is 14 years.

⁶⁷³ 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_0615, CI_LT_RF_LEDODPG_0615

Effective Date: June 2015

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 List⁶⁷⁴.

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS} * \text{ISR}$$

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.

⁶⁷⁴ DesignLights Consortium Qualified Products List

<http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>



Parking Garage or Canopy Fixture Baseline and Efficient Wattage⁶⁷⁵

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 applications⁶⁷⁶.
Otherwise, use site specific annual operating hours information.⁶⁷⁷

⁶⁷⁵ 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.

⁶⁷⁶ 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.



$$\begin{aligned} \text{ISR} &= \text{In Service Rate or percentage of units rebated that get installed} \\ &= 1.00^{678} \end{aligned}$$

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\begin{aligned} \Delta \text{kWh} &= ((288 - 162) / 1000) * 8,760 * 1.00 \\ &= 1104 \text{ kWh} \end{aligned}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{ISR} * \text{CF}$$

Where:

$$\begin{aligned} \text{CF} &= \text{Summer Peak Coincidence Factor for measure} \\ &= 0 \text{ for canopy applications and } 1.0 \text{ for parking garage} \\ &\text{applications}^{679} \end{aligned}$$

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta \text{kW} = ((288 - 162) / 1000) * 1.00 * 1.00$$

⁶⁷⁷ 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.

⁶⁷⁸ 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.

⁶⁷⁹ 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.

= 0.13 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs should be determined on a site-specific basis depending on the actual baseline and efficient equipment. The table below shows average NPV lifecycle incremental cost for time of sale and early replacement. If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.⁶⁸⁰

Measure Description	Time of Sale	Retrofit
LED Fixtures up to 150 W	\$621	\$803
LED Fixtures between 150W to 265W	\$1,305	\$1,516
LED Fixtures greater than 265 W	\$2,368	\$2,663

Measure Life

The measure life is assumed to be 21 years for canopy applications and 8 years for parking garage applications.⁶⁸¹

⁶⁸⁰ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

⁶⁸¹ The average rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 3/13/2015 http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php is 79,863 for parking garage luminaires (62,500 for retrofit kits) and 69,844 for canopy luminaires (80,000 for retrofit kits). For the purposes of this characterization, it is assumed the typical equipment will operate for 70,000 hours. Assuming average annual operating hours of 3,338 for canopy applications (Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey), the estimated measure life is 21 years. Assuming average annual operating hours of 8,760 for parking garage applications, the estimated measure life is 8 years.



Operation and Maintenance Impacts⁶⁸²

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 \$80.72 per lamp for time of sale and \$59.04 per lamp for early replacement for canopy applications and \$108.48 per lamp for time of sale and \$81.02 per lamp for early replacement for parking garage applications ⁶⁸³.

⁶⁸² 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.

⁶⁸³ 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_SSLEDWN_0516, CI_LT_EREP_SSLEDWN_0516

Effective Date: May 2016

End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp V2.0 in place of an incandescent lamp.

Definition of Baseline Condition

For time of sale replacement, the baseline wattage is assumed to be an incandescent or EISA compliant (where applicable) bulb installed in a screw-base socket.⁶⁸⁴ 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.

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

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBase = Based on lumens of the LED – find the equivalent baseline wattage from the table below. The table also shows the baseline shift from the EISA standards taking effect in 2020. See the section on baseline shift for how to apply the adjustment.

WattsEE = Actual LED lamp watts.

HOURS = Average hours of use per year.

⁶⁸⁴ For text of Energy and Independence and Security Act, see <http://www.gpo.gov/fdsys/pkg/PLAW-110publ140/pdf/PLAW-110publ140.pdf>



- = 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.⁶⁸⁵*
- ISR** *= In Service Rate or percentage of units rebated that are installed and operational*
= 1.00.⁶⁸⁶
- 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.

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase	Baseline Shift >=90 CRI	Baseline Shift <90 CRI
Standard A-Type (medium-base)	250	449	25	14%	16%
	450	799	29	25%	29%
	800	1099	43	26%	30%
	1100	1599	53	32%	36%
	1600	1999	72	31%	35%
	2000	2599	72	47%	52%
	2600	3000	150	20%	24%
	3001	5279	200	19%	22%
	5280	6000	300	17%	20%
Decorative (medium-base, > 499 lumens)	500	1050	43	17%	17%
Globe (medium-base, > 499 lumens)	500	574	43	11%	11%
	575	649	53	10%	10%
	650	1099	72	10%	10%
	1100	1300	150	6%	6%
3-Way, bug, marine, rough service, infrared	250	449	25	12%	12%
	450	799	40	14%	14%

⁶⁸⁵ 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.

⁶⁸⁶ 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.



Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase	Baseline Shift ≥ 90 CRI	Baseline Shift < 90 CRI
	800	1099	60	14%	14%
	1100	1599	75	17%	17%
	1600	1999	100	17%	17%
	2000	2549	125	17%	17%
	2550	2999	150	18%	18%
Globe (any base, < 500 lumens)	90	179	10	12%	12%
	180	249	15	13%	13%
	250	349	25	10%	10%
	350	499	40	9%	9%
Globe (candelabra or intermediate base, ≥ 500 lumens)	500	574	60	7%	7%
	575	649	75	6%	6%
	650	1099	100	7%	7%
	1100	1300	150	6%	6%
Decorative (Shapes B, BA, C, CA, DC, F, G, any base, < 500 lumens)	70	89	10	6%	6%
	90	149	15	6%	6%
	150	299	25	7%	7%
	300	500	40	8%	8%
Decorative (candelabra or intermediate base, ≥ 500 lumens)	500	1050	60	11%	11%
Reflector with medium screw bases w/ diameter ≤ 2.25"	400	449	40	7%	10%
	450	499	45	7%	10%
	500	649	50	8%	11%
	650	1199	65	11%	14%
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.5" (*see exceptions below)	640	739	40	14%	18%
	740	849	45	14%	19%
	850	1179	50	18%	23%
	1180	1419	65	17%	22%
	1420	1789	75	19%	24%
	1790	2049	90	19%	24%
	2050	2579	100	22%	27%
	2580	3429	120	25%	31%
	3430	4270	150	26%	32%
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	11%	15%
	630	719	45	12%	15%
	720	999	50	14%	18%
	1000	1199	65	14%	18%
	1200	1519	75	15%	19%



Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase	Baseline Shift ≥ 90 CRI	Baseline Shift < 90 CRI
	1520	1729	90	15%	19%
	1730	2189	100	17%	22%
	2190	2899	120	19%	24%
	2900	3850	150	21%	26%
*ER30, BR30, BR40, or ER40	400	449	40	7%	10%
	450	499	45	7%	10%
	500	649-1179	50	9%	12%
*BR30, BR40, or ER40	650	1419	65	13%	16%
*R20	400	449	40	7%	10%
	450	719	45	10%	13%
*All reflector lamps below lumen ranges specified above	200	299	20	9%	12%
	300	399-639	30	10%	13%

Baseline Adjustment

To account for new EISA standards going into effect in 2020, the savings for this measure should be reduced to account for the higher baselines. The baseline watts table above shows the calculated adjustments. The calculated energy savings for the applicable lamp should be multiplied by the appropriate factor from the baseline watts table for years 2020 and beyond⁶⁸⁷.

Summer Coincident Peak kW Savings Algorithm

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

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 $\text{WHFe} = \text{WHFd} = 1.0$.

CF = Summer Peak Coincidence Factor for measure

⁶⁸⁷ See 'ESTAR Integrated Screw SSL Lamp_032014.xls' for details. The Minimum Lamp Efficacy Requirements in ENERGY STAR Product Specification for Lamps (Light Bulbs) V2.0 vary by Color Rendering Index (CRI).



= 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.

$$\begin{aligned}\Delta\text{MMBTU} &= (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75 \\ &= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073\end{aligned}$$

Where:

- 0.7 = Aspect ratio.⁶⁸⁸
- 0.003413 = Constant to convert kWh to MMBTU.
- 0.23 = Fraction of lighting heat that contributes to space heating.⁶⁸⁹
- 0.75 = Assumed heating system efficiency.⁶⁹⁰

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.⁶⁹¹

Category	Time of Sale Incremental Cost
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⁶⁸⁸ 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.

⁶⁸⁹ 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).

⁶⁹⁰ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁶⁹¹ Cost assumptions are adapted from 2016 4th Quarter 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, 2016, for the Maryland and U.S. markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2016, Nielsen. Values are adjusted to reflect 2017 dollars.



Unknown	\$2.54
Globe	\$5.76
Reflector	\$3.52
A Lamp	\$3.85
Candelabra	\$5.42

Measure Life

The table below shows the assumed measure life for ENERGY STAR Version 2.0:

Lamp Type	ENERGY STAR V2.0 ⁶⁹²	
	Rated Life (Hours)	Measure Life (Years)
		Commercial Interior
Omnidirectional	15,000	4
Decorative	15,000	4
Directional	15,000 ⁶⁹³	4

Operation and Maintenance Impacts

To account for the shift in baseline due to the Federal Legislation, the leveled baseline replacement cost over the lifetime of the LED is calculated. The key assumptions used in this calculation are documented below⁶⁹⁴:

⁶⁹² The v2.0 ENERGY STAR Product Specification for Lamps (Light Bulbs) requires rated life of 15,000 hours for solid-state omnidirectional and decorative lamps, and 25,000 hours for solid-state directional lamps. Measure lifetimes assume 3,500 average annual operating hours.

⁶⁹³ The proposed ENERGY STAR V2.1 specifications will reduce rated life requirements to 15,000 hours for directional lamps. This revision has not yet been finalized, but finalization is expected shortly after the TRM publication date. Should the final published V2.1 specification differ from this assumption, the TRM will be revised.

⁶⁹⁴ Baseline incandescent lamp cost assumptions are adapted from 2016 4th Quarter 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, 2016, for the Maryland and U.S. markets and Expanded All Outlets Combined (xAOC) and Total Market Channels. Copyright © 2016, Nielsen.



	EISA 2012-2014 Compliant	EISA 2020 Compliant
Replacement Cost Unknown	\$1.52	\$1.79
Replacement Cost, Globe	\$1.58	\$2.17
Replacement Cost, Reflector	\$3.63	\$4.68
Replacement Cost, A Lamp	\$1.87	\$1.71
Replacement Cost, Candelabra	\$1.09	\$1.71
Component Life (hours)	1,000	2,000

The calculated default net present values of lamp replacements over the measure life for time of sale applications are presented below⁶⁹⁵.

Bulb Type	Indoor
Unknown	\$52.67
Globe	\$53.43
Reflector	\$79.32
A Lamp	\$57.09
Candelabra	\$47.24

⁶⁹⁵ See "Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx" for calculations. Analysis assumes a discount rate of 5%.



LED Refrigerated Case Lighting

Unique Measure Code(s): CI_LT_TOS_LEDRL_0615, CI_LT_RF_LEDRL_0615

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to the installation of LED luminaires in vertical and horizontal refrigerated display cases replacing T8 or T12HO linear fluorescent lamp technology. Savings characterizations are provided for both coolers and freezers. Specified LED luminaires should meet v2.1 DesignLights Consortium Product Qualification Criteria for either the “Vertical Refrigerated Case Luminaire” or “Horizontal Refrigerated Case Luminaires” category. LED luminaires not only provide the same light output with lower connected wattages, but also produce less waste heat which decreases the cooling load on the refrigeration system and energy needed by the refrigeration compressor. Savings and assumptions are based on a per linear foot of installed lighting basis.

Definition of Baseline Condition

The baseline equipment is assumed to be T8 or T12HO linear fluorescent lamps.

Definition of Efficient Condition

The efficient equipment is assumed to be DesignLights Consortium qualified LED vertical or horizontal refrigerated case luminaires.

Annual Energy Savings Algorithm

$$\Delta kWh = (WattsPerLF_{BASE} - WattsPerLF_{FEE}) / 1000 * LF * HOURS * WHFe.$$

Where:

WattsPerLF_{BASE} = Connected wattage per linear foot of the baseline fixtures; see table below for default values.⁶⁹⁶

WattsPerLF_{FEE} = Connected wattage per linear foot of the LED fixtures.⁶⁹⁷

⁶⁹⁶ Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

⁶⁹⁷ Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.



= Actual installed. If actual installed wattage is unknown, see table below for default values.

Efficient Lamp	Baseline Lamp	Efficient Fixture Wattage (WattsPerLFEE)	Baseline Fixture Watts (WattsPerLFBASE)
LED Case Lighting System	T8 Case Lighting System	7.6	15.2
LED Case Lighting System	T12HO Case Lighting System	7.7	18.7

LF = Linear feet of installed LED luminaires.
 = Actual installed
 HOURS = Annual operating hours; assume 6,205 operating hours per year if actual operating hours are unknown.⁶⁹⁸
 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.⁶⁹⁹

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\text{WattsPerLFBASE} - \text{WattsPerLFEE}) / 1000 * LF * WHFd * CF.$$

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.⁷⁰⁰

CF = Summer Peak Coincidence Factor for measure

⁶⁹⁸ 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.

⁶⁹⁹ 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.

⁷⁰⁰ 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.



$$= 0.96 \text{ (lighting in Grocery)}.^{701}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost⁷⁰²

Per Linear Foot
Time of Sale
\$23

Measure Life⁷⁰³

The expected measure life is assumed to be 8 years.

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 \$1.48 for time of sale applications⁷⁰⁴.

⁷⁰¹ 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.

⁷⁰² Navigant. May 2014. Incremental Cost Study Phase Three Final Report. Prepared for NEEP Regional Evaluation, Measurement & Verification Forum

⁷⁰³ The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <<https://www.designlights.org/resources/file/NEEPDLCQPL>> is 50,000 hours. Assuming average annual operating hours of 6,205, the estimated measure life is 8 years.

⁷⁰⁴ See “Mid-Atlantic TRM Lighting Adjustments and O&M.xlsx” for calculations. Analysis assumes a discount rate of 5%.



Exterior LED Flood and Spot Luminaires

Unique Measure Code(s): CI_LT_TOS_LEDFLS_0615 and CI_LT_RF_LEDFLS_0615

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to the installation of an exterior LED flood or spot luminaire for landscape or architectural illumination applications in place of a halogen incandescent or high-intensity discharge light source. Eligible applications include time of sale and new construction as well as retrofit applications.

Definition of Baseline Condition

The baseline condition is defined as an exterior flood or spot fixture with a high intensity discharge or PAR light-source. Typical baseline technologies include halogen incandescent parabolic aluminized reflector (PAR) lamps and metal halide (MH) luminaires.

Definition of Efficient Condition

The efficient condition is defined as an LED flood or spot luminaire. Eligible luminaires must be listed on the DesignLights Consortium Qualified Products List⁷⁰⁵.

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.⁷⁰⁶*

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
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⁷⁰⁵ DesignLights Consortium Qualified Products List <<https://www.designlights.org/qpl>>

⁷⁰⁶ 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.



Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
PAR38	500	1000	52.5
	1000	4000	108.7
Metal Halide	4000	15000 ⁷⁰⁷	205.0
Metal Halide	15000	20000	288
Metal Halide	20000	30000	460

WattsEE = Actual Connected load of the LED luminaire.

HOURS = Average hours of use per year.

= If annual operating hours are unknown, assume 3,338 ⁷⁰⁸.

Otherwise, use site specific annual operating hours information.⁷⁰⁹

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * CF.$$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0. ⁷¹⁰

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

⁷⁰⁷ 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.

⁷⁰⁸ Efficiency Vermont TRM User Manual No. 2014-85b; based on 5 years of metering on 235 outdoor circuits in New Jersey.

⁷⁰⁹ 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.

⁷¹⁰ It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

lifecycle incremental cost for time of sale and early replacement. If additional detail is needed, a further disaggregation of the IMCs, based on wattage ranges, can be found in the cited workbook.⁷¹¹

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

The measure life is assumed to be 15 years.⁷¹²

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.⁷¹³

⁷¹¹ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using data from California IOU work papers cited in that document. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at <http://www.neep.org/file/5548/download?token=pLIMjfvz>.

⁷¹² The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <<https://www.designlights.org/resources/file/NEEPDLCQPL>> is 50,000 hours for Architectural Flood and Spot Luminaires and 100,000 hours for Landscape/Accent Flood and Spot Luminaires. 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 for Architectural Flood and Spot Luminaires and 30 years for Landscape/Accent Flood and Spot Luminaires. By convention, measure life of C&I LED lighting is capped at 15 years.

⁷¹³ 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.



LED Four-Foot Linear Replacement Lamps

Unique Measure Code(s): CI_LT_RF_LED TUBE_0615

Effective Date: June 2015

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:⁷¹⁴

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.

⁷¹⁴ 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 List⁷¹⁵.

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 Assumptions⁷¹⁶

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

⁷¹⁵ DesignLights Consortium Qualified Products List <<http://www.designlights.org/QPL>>

⁷¹⁶ 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.



28W T5 NLO ⁷¹⁷	32	13	19
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- HOURS** = Average hours of use per year.
= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D.⁷¹⁸
Otherwise, use site specific annual operating hours information.⁷¹⁹
- ISR** = In Service Rate or percentage of units rebated that get installed.
= 1.00.⁷²⁰
- 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.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF}.$$

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

⁷¹⁷ The T5 wattage with ballast losses was sourced from:

<https://www.xcelenergy.com/staticfiles/xcel/Marketing/MN-Bus-Lighting-Input-Wattage-Guide.pdf>

⁷¹⁸ 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 hours; however, LED operating hours are a potential candidate for future study.

⁷¹⁹ 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.

⁷²⁰ 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.



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.

$$\begin{aligned}\Delta\text{MMBTU} &= (-\Delta\text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75. \\ &= (-\Delta\text{kWh} / \text{WHFe}) * 0.00073.\end{aligned}$$

Where:

0.7 = Aspect ratio. ⁷²¹
0.003413 = Constant to convert kWh to MMBTU.
0.23 = Fraction of lighting heat that contributes to space heating ⁷²²
0.75 = Assumed heating system efficiency. ⁷²³

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs (equipment and labor) LED linear replacement lamps are as follows.⁷²⁴

Type A: \$22.67 per LED replacement lamp, \$47.50 for the ballast.

⁷²¹ 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.

⁷²² 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).

⁷²³ Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

⁷²⁴ 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).



Type C: \$22.67 per LED replacement lamp, \$15.07 for the external driver.

Measure Life

The measure life is assumed to be 14 years.⁷²⁵

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.⁷²⁶

⁷²⁵ The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <<https://www.designlights.org/resources/file/NEEPDLCQPL>> is 50,000 hours. Assuming average annual operating hours of 3,500 for a typical commercial lighting application, the estimated measure life is 14 years.

⁷²⁶ 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.



Heating Ventilation and Air Conditioning (HVAC) End Use

Unitary HVAC Systems

Unique Measure Code(s): CI_HV_TOS_HVACSYS_0516, CI_HV_EREP_HVACSYS_0516

Effective Date: May 2016

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)⁷²⁷ 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.

⁷²⁷ 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	Before January 1, 2018		On or After January 1, 2018
		Baseline Condition (IECC 2012)	Baseline Condition (IECC 2015)	Baseline Condition (Federal Standards) ⁷²⁸
Air Conditioners, Air Cooled				
<65,000 Btu/h	Split system	13.0 SEER	13.0 SEER	Unchanged
	Single package	14.0 SEER ⁷²⁹	14.0 SEER	Unchanged
≥65,000 Btu/h and <135,000 Btu/h	Split system and single package	11.2 EER 11.4 IEER	11.2 EER 12.8 IEER	11.3 EER 12.9 IEER
≥135,000 Btu/h and <240,000 Btu/h	Split system and single package	11.0 EER 11.2 IEER	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 10.1 IEER	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	Unchanged
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	Unchanged
≥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	Unchanged
≥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	Unchanged
≥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	Unchanged
≥760,000 Btu/h	Split system and single package	12.0 EER 12.4 IEER	12.2 EER 13.5 IEER	Unchanged

⁷²⁸ 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.

⁷²⁹ Federal standard is more stringent than IECC 2012 and therefore establishes the baseline for this equipment. See 10 CFR 431.97.



Size Category (Cooling Capacity)	Subcategory	Before January 1, 2018		On or After January 1, 2018
		Baseline Condition (IECC 2012)	Baseline Condition (IECC 2015)	Baseline Condition (Federal Standards) ⁷²⁸
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	Unchanged
≥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	Unchanged
≥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	Unchanged
≥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	Unchanged
≥760,000 Btu/h	Split system and single package	11.7 EER 11.9 IEER	11.7 EER 11.9 IEER	Unchanged
Heat Pumps, Air Cooled ⁷³⁰				
<65,000 Btu/h	Split System	14.0 SEER ⁷³¹ 8.2 HSPF	14.0 SEER 8.2 HSPF	Unchanged
	Single Package	14.0 SEER ⁷³² 8.0 HSPF	14.0 SEER 8.0 HSPF	Unchanged
≥65,000 Btu/h and <135,000 Btu/h	Split system and single package	11.0 EER 11.2 IEER 3.3 COP	11.0 EER 12.0 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 10.7 IEER 3.2 COP	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 9.6 IEER 3.2 COP	9.5 EER 10.6 IEER 3.2 COP	9.5 EER 10.6 IEER 3.2 COP

⁷³⁰ Heating mode efficiencies for heat pumps ≥65,000 Btu/h are provided at the 47°F db/43° wb outdoor air rating condition.

⁷³¹ Federal standard is more stringent than IECC 2012 and therefore establishes the baseline for this equipment. See Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.97 (2017).

⁷³² Federal standard is more stringent than IECC 2012 and therefore establishes the baseline for this equipment. See Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.96 (2017).

Size Category (Cooling Capacity)	Subcategory	Baseline Condition (Federal Standards) ⁷³³
Packaged Terminal Air Conditioners^{734,735}		
All Capacities	New Construction (Standard Size) ⁷³⁶	14.0 – (0.300 * Cap/1000) EER
All Capacities	Replacement (Non-Standard Size)	10.9 – (0.213 * Cap/1000) EER
Packaged Terminal Heat Pumps^{737,738}		
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

⁷³³ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.96 (2016).

⁷³⁴ 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.

⁷³⁵ “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.

⁷³⁶ 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.

⁷³⁷ 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.

⁷³⁸ “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.



Air Conditioners (includes air-, water-, and evaporatively-cooled unitary ACs and PTACs)

Time of Sale:

For units with capacities less than 65,000 Btu/h and all PTACs, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$$\Delta \text{kWh} = (\text{Btu/h}/1000) * ((1/\text{SEERBASE}) - (1/\text{SEEREE})) * \text{HOURS}.$$

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:

$$\Delta \text{kWh} = (\text{Btu/h}/1000) * ((1/\text{IEERBASE}) - (1/\text{IEEREE})) * \text{HOURS}.$$

Early Replacement⁷³⁹:

For units with capacities less than 65,000 Btu/h and 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):

$$= (\text{Btu/h}/1000) * ((1/\text{SEEREXIST}) - (1/\text{SEEREE})) * \text{HOURS}.$$

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

$$= (\text{Btu/h}/1000) * ((1/\text{SEERBASE}) - (1/\text{SEEREE})) * \text{HOURS}.$$

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:

⁷³⁹ 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):

$$= (\text{Btu/h}/1000) * ((1/\text{IEER}_{\text{EXIST}}) - (1/\text{IEER}_{\text{EE}})) * \text{HOURS}.$$

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

$$= (\text{Btu/h}/1000) * ((1/\text{IEER}_{\text{BASE}}) - (1/\text{IEER}_{\text{EE}})) * \text{HOURS}.$$

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:

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

$$\Delta kWh_{\text{COOL}} = (\text{Btu/h}_{\text{COOL}}/1000) * ((1/\text{SEER}_{\text{BASE}}) - (1/\text{SEER}_{\text{EE}})) * \text{HOURS}_{\text{COOL}}.$$

$$\Delta kWh_{\text{HEAT}} = (\text{Btu/h}_{\text{HEAT}}/1000) * ((1/\text{HSPF}_{\text{BASE}}) - (1/\text{HSPF}_{\text{EE}})) * \text{HOURS}_{\text{HEAT}}.$$

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:

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

$$\Delta kWh_{\text{COOL}} = (\text{Btu/h}_{\text{COOL}}/1000) * ((1/\text{IEER}_{\text{BASE}}) - (1/\text{IEER}_{\text{EE}})) * \text{HOURS}_{\text{COOL}}.$$

$$\Delta kWh_{\text{HEAT}} = (\text{Btu/h}_{\text{HEAT}}/3412) * ((1/\text{COP}_{\text{BASE}}) - (1/\text{COP}_{\text{EE}})) * \text{HOURS}_{\text{HEAT}}.$$

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

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

$$\Delta kWh_{\text{COOL}} = (\text{Btu/h}_{\text{COOL}}/1000) * ((1/\text{EER}_{\text{BASE}}) - (1/\text{EER}_{\text{EE}})) * \text{HOURS}_{\text{COOL}}.$$

$$\Delta kWh_{\text{HEAT}} = (\text{Btu/h}_{\text{HEAT}}/3412) * ((1/\text{COP}_{\text{BASE}}) - (1/\text{COP}_{\text{EE}})) * \text{HOURS}_{\text{HEAT}}.$$



Early Replacement⁷⁴⁰:

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 (i.e., measure life less the age of the existing equipment):

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

$$\Delta kWh_{COOL} = (Btu/h_{COOL}/1000) * ((1/SEER_{EXIST}) - (1/SEER_{EE})) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (Btu/h_{HEAT}/1000) * ((1/HSPF_{EXIST}) - (1/HSPF_{EE})) * HOURS_{HEAT}.$$

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

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

$$\Delta kWh_{COOL} = (Btu/h_{COOL}/1000) * ((1/SEER_{BASE}) - (1/SEER_{EE})) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (Btu/h_{HEAT}/1000) * ((1/HSPF_{BASE}) - (1/HSPF_{EE})) * HOURS_{HEAT}.$$

For units with capacities greater than or equal to 65,000 Btu/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

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

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

$$\Delta kWh_{COOL} = (Btu/h_{COOL}/1000) * ((1/IEER_{EXIST}) - (1/IEER_{EE})) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (Btu/h_{HEAT}/3412) * ((1/COPEX_{EXIST}) - (1/COPEE)) * HOURS_{HEAT}.$$

⁷⁴⁰ 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 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 (i.e., measure life less the age of the existing equipment):

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

$$\Delta kWh_{COOL} = (Btu/h_{COOL}/1000) * ((1/EEREXIST) - (1/EEREE)) * HOURS_{COOL}.$$

$$\Delta kWh_{HEAT} = (Btu/h_{HEAT}/3412) * ((1/COPEEXIST) - (1/COPEE)) * HOURS_{HEAT}.$$

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.



	<i>= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.</i>
SEEREXIST	<i>= SEER of the existing unit.</i>
	<i>= Actual.</i>
HSPFEE	<i>= HSPF of efficient unit.</i>
	<i>= Actual Installed.</i>
HSPFBASE	<i>= HSPF of baseline unit.</i>
	<i>= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.</i>
HSPFEXIST	<i>= HSPF of the existing unit.</i>
	<i>= Actual.</i>
IEEREE	<i>= IEER of efficient unit.</i>
	<i>= Actual Installed.</i>
IEERBASE	<i>= IEER of baseline unit.</i>
	<i>= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.</i>
IEEREXIST	<i>= IEER of the existing unit.</i>
	<i>= Actual.</i>
COPEE	<i>= COP of efficient unit.</i>
	<i>= Actual Installed.</i>
COPBASE	<i>= COP of baseline unit.</i>
	<i>= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.</i>
COPEEXIST	<i>= COP of the existing unit.</i>
	<i>= Actual.</i>
EERBASE	<i>= EER of baseline unit.</i>
	<i>= Based on IECC 2012 or 2015 for the installed capacity. See table above.</i>
EEREE	<i>= EER of efficient unit (If the actual EER is unknown, it may be approximated by using the following equation: $EER = SEER/1.2$)</i>
	<i>= Actual installed.</i>
EEREXIST	<i>= EER of existing unit.</i>
	<i>= Actual.</i>
3412	<i>= Conversion factor (Btu/kWh).</i>
HOURS _{COOL}	<i>= Full load cooling hours.⁷⁴¹</i>

⁷⁴¹ 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



*= 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.*

*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” below.
Otherwise, use site specific full load heating hours information.*

Full Load Cooling Hours by Location and Building Type (HOURS_{COOL})⁷⁴²

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

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.”

⁷⁴² 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 - 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



Full Load Heating Hours by Location and Building Type (HOURS_{HEAT})⁷⁴³

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

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

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

⁷⁴³ 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.



Early Replacement:

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

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

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

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

Where:

CF_{PJM} = PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.360 for units <135 kBtu/h and 0.567 for units ≥ 135 kBtu/h.⁷⁴⁴

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.⁷⁴⁵

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.⁷⁴⁶ Prescribed values vary depending on the current

⁷⁴⁴ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

⁷⁴⁵ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

⁷⁴⁶ Default incremental costs assumptions for water- and evaporatively-cooled ACs, PTACs, and PTHPs will be addressed in subsequent versions of the TRM, when available. In the interim, incremental costs for these equipment types should be determined on a site-specific basis.



building code, the date of installation, and whether the baseline condition is time of sale or early replacement.⁷⁴⁷

Time of Sale Air-Cooled Unitary Air Conditioners Incremental Costs (\$/ton)⁷⁴⁸

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

⁷⁴⁷ Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 – 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

⁷⁴⁸ Incremental costs in this table assume CEE Tier 2 efficiency as presented in Consortium for Energy Efficiency. 2016. CEE Commercial Unitary Air-Conditioning and Heat Pumps Specification, Effective January 12, 2016. Costs are from Itron, *Mid-Atlantic TRM Version 7.0 Incremental Costs Update*, 2017. Measure and baseline costs were calculated using hedonic models and data from Itron, *2010 – 2012 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA



Time of Sale Air-Source Unitary Heat Pumps Incremental Costs (\$/ton)⁷⁴⁹

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

⁷⁴⁹ 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 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA



Early Replacement Air-Cooled Unitary Air Conditioners Costs and Deferred Replacement Credits (\$/ton)⁷⁵⁰

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

⁷⁵⁰ 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)⁷⁵¹

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.⁷⁵²

Operation and Maintenance Impacts

n/a

⁷⁵¹ 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 W0017 Ex Ante Measure Cost Study*, conducted for the California Public Utility Commission in 2014. Results are adjusted for inflation and to reflect differences in Maryland labor rates. Calculations, data and sources are available at http://www.neep.org/file/5549/download?token=S3weM_MA

⁷⁵² 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_0615, CI_HV_EREP_DMSHP_0615

Effective Date: June 2015

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.⁷⁵³ 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.

⁷⁵³ 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 Efficiency⁷⁵⁴

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 ⁷⁵⁵	All	13	11.2
Packaged Air Conditioners ⁷⁵⁶	All	14	11.8
Packaged Air Source Heat Pumps ⁷⁵⁷	All	14	11.8

Baseline Heating System Efficiency

⁷⁵⁴ Federal standards.

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

⁷⁵⁵ Federal Standard as of January 1, 2015.

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

⁷⁵⁶ Ibid.

⁷⁵⁷ Ibid



Equipment Type	Efficiency Metric	Efficiency
Gas Boiler ⁷⁵⁸	AFUE	82%
Air Source Heat Pump – Split System ⁷⁵⁹	HSPF	8.2
Air Source Heat Pump - Packaged	HSPF	8.0
Electric Resistance ⁷⁶⁰	HSPF	3.41

Annual Energy Savings Algorithm

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

$$\Delta kWh_{cool} = CCAP \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}.$$

$$\Delta kWh_{heat}^{761} = HCAP \times (ELECHEAT/HSPF_{base} - 1/HSPF_{ee}) \times EFLH_{heat}.$$

Where:

- CCAP* = Cooling capacity of DMSHP unit, in kBtu/hr.
- SEER_{base}* = SEER of baseline unit. If unknown, use 9.8⁷⁶².
- SEER_{ee}* = SEER of actual DMSHP. If unknown, use ENERGYSTAR minimum of 15.
- EFLH_{cool}* = Full load hours for cooling equipment. See table below for default values.
- 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.⁷⁶³
- HSPF_{ee}* = HSPF of actual DMSHP. If unknown, 8.5.
- EFLH_{heat}* = Full load hours for heating equipment. See table below for default values.

⁷⁵⁸ Federal Standards for gas boilers

⁷⁵⁹ Federal standards for air source heat pumps

⁷⁶⁰ Electric heat has a COP of 1.0. Converted into HSPF units this is approximately 3.41.

⁷⁶¹ 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.

⁷⁶² Federal standard for typical window AC sizes with louvered sides.

⁷⁶³ If unknown, assume the baseline is a gas furnace, with no electrical savings



Full Load Cooling Hours by Location and Building Type (HOURS_{COOL})⁷⁶⁴

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

⁷⁶⁴ 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 (HOURS_{HEAT})⁷⁶⁵

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

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = CCAP \times (1/EER_{base} - 1/EER_{ee}) \times CF.$$

Where:

⁷⁶⁵ 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.



EER_{base} = EER of baseline unit. If unknown, use 9.8⁷⁶⁶.
 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.⁷⁶⁷
 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.⁷⁶⁸

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes increased fossil fuel consumption.

$$\Delta \text{MMBtu} = \text{HCAP} \times \text{EFLH}_{\text{heat}} / \text{AFUE} / 1,000$$

Where:

$\text{EFLH}_{\text{heat}}$ = Full load hours for heating equipment. See table above.
 AFUE = AFUE of baseline equipment. If unknown use 82%.⁷⁶⁹

Incremental Cost

The full installed cost of the ductless mini-split system is shown below.⁷⁷⁰

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

⁷⁶⁶ Federal standard for typical window AC sizes with louvered sides.

⁷⁶⁷ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011

⁷⁶⁸ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011.

⁷⁶⁹ Federal standard for gas boilers.

⁷⁷⁰ Navigant, Inc. Incremental Cost Study Phase 2. January 16, 2013. Table 16.



Capacity (kBtu/h)	Efficiency			
	13 SEER	18 SEER	21 SEER	26 SEER
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 ⁷⁷¹	\$170/unit
Gas furnace ⁷⁷²	\$1,606/unit
Electric Baseboard ⁷⁷³	\$0 ⁷⁷⁴

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.⁷⁷⁵

Operation and Maintenance Impacts

n/a

⁷⁷¹ Energy Star Calculator.

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

⁷⁷² 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

⁷⁷³ If existing case is electric resistance heat, assume project replaces existing functional baseboard.

⁷⁷⁴ 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.

⁷⁷⁵ 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.



Variable Frequency Drive (VFD) for HVAC

Unique Measure Code(s): CI_MO_RF_VFDRIVE_0516

Effective Date: May 2016

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.

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 Algorithm⁷⁷⁶

HVAC Fan Applications

$$\Delta kWh = \Delta kWh_{FAN} * (1 + IE_{ENERGY})$$

$$\Delta kWh_{FAN} = kWh_{BASE} - kWh_{RETRO}$$

$$kWh_{BASE} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}} \right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{BASE})$$

$$kWh_{RET} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}} \right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{RET})$$

⁷⁷⁶ 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%.⁷⁷⁷
- 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%

⁷⁷⁷ 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

$$\begin{aligned}\Delta kW &= \Delta kW_{FAN} * (1 + IE_{DEMAND}). \\ \Delta kW_{FAN} &= \Delta kW_{BASE} - \Delta kW_{RETRO}. \\ \Delta kW_{BASE} &= (0.746 * HP * LF / \eta_{MOTOR}) * PLR_{BASE, PEAK}. \\ \Delta kW_{RETRO} &= (0.746 * HP * LF / \eta_{MOTOR}) * PLR_{RETRO, PEAK}.\end{aligned}$$

Where:

- ΔkW_{FAN} = Fan-only annual demand savings (kW).
- IE_{DEMAND} = HVAC interactive effects factor for demand.
= If unknown, assume 0%.⁷⁷⁸
- 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 %).

⁷⁷⁸ 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.



$PLR_{RETRO, PEAK}$ = PLR for the average flow fraction during summer peak period for retrofit flow control type (default average flow fraction during peak period = 100%).

HVAC Pump Applications

$$\Delta kW = ((HP * 0.746 * LF) / \eta_{MOTOR}) * DSF * CF.$$

Where:

DSF = Demand Savings Factor (see table “Energy and Demand Savings Factors” below).

CF = Summer Peak Coincidence Factor for measure
= 0.55.⁷⁷⁹

VFD Operating Hours by Application and Building Type ($RHRS_{BASE}$)⁷⁸⁰

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

⁷⁷⁹ UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives – Pumps.

⁷⁸⁰ 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
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*
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



Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
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 Factors⁷⁸¹

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

⁷⁸¹ 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.



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.⁷⁸²

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.⁷⁸³

Operation and Maintenance Impacts

n/a

⁷⁸² 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

⁷⁸³ Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.



REGIONAL EVALUATION,
MEASUREMENT & VERIFICATION FORUM



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:

$$\Delta \text{kWh} = \text{TONS} * (\text{IPLV}_{\text{base}} - \text{IPLV}_{\text{ee}}) * \text{HOURS}.$$



Early Replacement⁷⁸⁴:

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

$$= \text{TONS} * (\text{IPLV}_{\text{exist}} - \text{IPLV}_{\text{ee}}) * \text{HOURS}.$$

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

$$= \text{TONS} * (\text{IPLV}_{\text{base}} - \text{IPLV}_{\text{ee}}) * \text{HOURS}.$$

Where:

TONS	<i>= Total installed capacity of the water chilling package[tons]. = Actual Installed.</i>
IPLV _{exist}	<i>= Integrated Part Load Value (IPLV)⁷⁸⁵ of the existing equipment [kW/ton].</i>
IPLV _{base}	<i>= 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.⁷⁸⁶</i>
IPLV _{ee}	<i>= Integrated Part Load Value (IPLV) of the efficient equipment [kW/ton]. = Actual Installed.</i>
HOURS	<i>= 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.</i>

⁷⁸⁴ 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.

⁷⁸⁵ Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

⁷⁸⁶ 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:

$$\Delta kW = \text{TONS} * (\text{Full_Loadbase} - \text{Full_Loadee}) * CF.$$

Early replacement:

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

$$= \text{TONS} * (\text{Full_Loadexist} - \text{Full_Loadee}) * CF.$$

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

$$= \text{TONS} * (\text{Full_Loadbase} - \text{Full_Loadee}) * CF.$$

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 below⁷⁸⁷

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

= 0.808.⁷⁸⁸

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

= 0.923.⁷⁸⁹

Annual Fossil Fuel Savings Algorithm

⁷⁸⁷ 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

⁷⁸⁸ 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.

⁷⁸⁹ Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

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.⁷⁹⁰ 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
150	10.1	N/A	\$18	\$49	\$69

⁷⁹⁰ 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
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 years⁷⁹¹.

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency for Washington, D.C. and Delaware⁷⁹²

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.

⁷⁹¹ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "[http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf](http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf)"

⁷⁹² 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 Maryland⁷⁹³

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.

⁷⁹³ 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)⁷⁹⁴

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

⁷⁹⁴ 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

$$\Delta \text{MMBtu} = \text{CAP} * \text{HOURS} * (1/\text{EFF}_{\text{base}} - 1/\text{EFF}_{\text{ee}}) / 1,000,000.$$

Where:

CAP = Equipment capacity [Btu/h].

= Actual Installed.

HOURS = Full Load Heating Hours.



	<i>= See "Full Load Heating Hours by Location and Building Type" table in the "Reference Tables" section below.⁷⁹⁵</i>
EFF_{base}	<i>= 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.</i>
	<i>= For time of sale: See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below⁷⁹⁶</i>
	<i>equipment.</i>
EFF_{ee}	<i>= 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.</i>
	<i>= Actual Installed.</i>
1,000,000	<i>= Btu/MMBtu unit conversion factor.</i>

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 years⁷⁹⁷.

Operation and Maintenance Impacts

n/a

Reference Tables

⁷⁹⁵ 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.

⁷⁹⁶ 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.

⁷⁹⁷ Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.



Time of Sale Baseline Equipment Efficiency⁷⁹⁸

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 Costs⁷⁹⁹

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

⁷⁹⁸ Baseline efficiencies based on current federal standards:

http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf.

⁷⁹⁹ 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})⁸⁰⁰

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

⁸⁰⁰ 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 Algorithm⁸⁰¹

$$\Delta \text{kWh} = 733 \text{ kWh.}^{802}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = 0.19 \text{ kW.}^{803}$$

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBtu} = \text{CAP} * \text{HOURS} * ((1/\text{AFUE}_{\text{base}}) - (1/\text{AFUE}_{\text{ee}})) / 1,000,000.$$

⁸⁰¹ Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

⁸⁰² 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.

⁸⁰³ Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.



Where:

- CAP* = Capacity of the high-efficiency equipment [Btu/h].
= Actual Installed.
- HOURS* = Full Load Heating Hours
= See "Full Load Heating Hours by Location and Building Type" table in the "Reference Tables" section below.⁸⁰⁴
- AFUE_{base}* = Annual Fuel Utilization Efficiency of the baseline equipment.
= For time of sale: 0.80.⁸⁰⁵
- 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.⁸⁰⁶

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

⁸⁰⁴ 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.

⁸⁰⁵ 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.

⁸⁰⁶ 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.

98%	\$659
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Measure Life

The measure life is assumed to be 18 years⁸⁰⁷.

Operation and Maintenance Impacts

n/a

Reference Tables

Full Load Heating Hours by Location and Building Type (HOURS_{HEAT})⁸⁰⁸

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

⁸⁰⁷ Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "[http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf](http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf)"

⁸⁰⁸ 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.
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



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

$$\Delta \text{kWh} = \text{TONS} * \text{SF}$$

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.⁸⁰⁹

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = 0 \text{ kW}.$$
⁸¹⁰

⁸⁰⁹ 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.



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 Costs⁸¹¹

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 years⁸¹².

Operation and Maintenance Impacts

n/a

⁸¹⁰ Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

⁸¹¹ Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

⁸¹² General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.



Reference Tables

Savings Factors⁸¹³

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

⁸¹³ 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_0615

Effective Date: June 2015

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.⁸¹⁴ 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

$$\Delta \text{kWh} = \text{CCAP} \times \text{EFLH} \times 1/\text{SEER}_{\text{pre}} \times \%_{\text{impr.}}$$

Where:

CCAP = Cooling capacity of existing AC unit, in kBtu/hr.

⁸¹⁴ 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. See table below

%_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 = 0.05.⁸¹⁵

Full Load Cooling Hours by Location and Building Type (EFLH)⁸¹⁶

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

⁸¹⁵ Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

⁸¹⁶ 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	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

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}* = 0.05.⁸¹⁷
- 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.⁸¹⁸
- 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.⁸¹⁹

Annual Fossil Fuel Savings Algorithm

⁸¹⁷ Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

⁸¹⁸ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011

⁸¹⁹ C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011. Final values are presented in Metoyer, Jarred, "Report Revision Memo," KEMA, August 2011



n/a

Incremental Cost

Use the actual cost of the tune-up. If this is unknown, use a default of \$35/ton⁸²⁰.

Measure Life

The measure life for an AC tune-up is 5 years.⁸²¹

Operation and Maintenance Impacts

n/a

⁸²⁰ Illinois Statewide Technical Reference Manual for Energy Efficiency Version 4.0 Final February 24 2015

⁸²¹ 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.



Refrigeration End Use

ENERGY STAR Commercial Freezers

Unique Measure Code(s): CI_RF_TOS_FREEZER_0614

Effective Date: June 2014

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.

Definition of Baseline Condition

The baseline condition is a standard-efficiency packaged commercial freezer meeting, but not exceeding, federal energy efficiency standards.

Definition of Efficient Condition

The efficient condition is a high-efficiency packaged commercial freezer meeting ENERGY STAR Version 4.0 requirements⁸²².

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = (\text{kWhBASEdaily}_{\text{max}} - \text{kWhEEdaily}_{\text{max}}) * 365.$$

Where:

$\text{kWhBASEdaily}_{\text{max}}$ ⁸²³ = See table below.

Product Volume (in cubic feet)	Freezer
Vertical Closed	
<i>Solid</i>	<i>VCS.SC.L</i>
All volumes	$0.22V + 1.38$
<i>Transparent</i>	<i>VCT.SC.L</i>
All volumes	$0.29V + 2.95$
Horizontal Closed	

⁸²² ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

⁸²³ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).



<i>Solid</i>	<i>HCS.SC.L</i>
All volumes	$0.06V+1.12$
<i>Transparent</i>	<i>HCT.SC.L</i>
All volumes	$0.08V+1.23$

Where V = Association of Home Appliances Manufacturers (AHAM) volume

* 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)).)

$kWhEEdaily_{max}^{824}$ = See table below.

Product Volume (in cubic feet)	Freezer (<i>kWhEEdaily</i> <i>max</i>)
Vertical Closed	
<i>Solid</i>	<i>VCS.SC.L</i>
$0 < V < 15$	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
<i>Transparent</i>	<i>VCT.SC.L</i>
$0 < V < 15$	0.232V+2.36
$15 \leq V < 30$	
$30 \leq V < 50$	
$50 \leq V$	
Horizontal Closed	
<i>Solid or Transparent</i>	<i>HCT.SC.L, HCS.SC.L</i>
All volumes	0.057V+0.55

Where V = Association of Home Appliances Manufacturers (AHAM) volume.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh/HOURS) \times CF.$$

Where:

⁸²⁴ ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.



$$\begin{aligned} \text{HOURS} &= \text{Full load hours.} \\ &= 5858.^{825} \\ \text{CF} &= \text{Summer Peak Coincidence Factor for measure.} \\ &= 0.772.^{826} \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost⁸²⁷

The incremental cost for this time of sale measure is assumed to be \$0.⁸²⁸

Measure Life

The measure life is assumed to be 12 years.⁸²⁹

Operation and Maintenance Impacts

n/a

⁸²⁵ Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

⁸²⁶ 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.

⁸²⁷ Unit Energy Savings (UES) Measures and Supporting Documentation, ComFreezer_v3_0.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum

⁸²⁸ Energy Star Calculator accessed April 25, 2017, which cites Energy Star research, 2014.

⁸²⁹ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.



ENERGY STAR Commercial Refrigerator

Unique Measure Code(s): CI_RF_TOS_REFRIG_0614

Effective Date: June 2014

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.

Definition of Baseline Condition

The baseline condition is a standard-efficiency packaged commercial refrigerator meeting, but not exceeding, federal energy efficiency standards.

Definition of Efficient Condition

The efficient condition is a high-efficiency packaged commercial refrigerator meeting ENERGY STAR Version 4.0 requirements.⁸³⁰

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdaily_{max} - kWhEEdaily_{max}) * 365.$$

Where:

$kWhBASEdaily_{max}$ ⁸³¹ = See table below.

Product Volume (in cubic feet)	Refrigerator ($kWhBASEdaily_{max}$)
Vertical Closed	
<i>Solid</i>	$VCS.SC.M^*$
All volumes	$0.05V+1.36$
<i>Transparent</i>	$VCT.SC.M$
All volumes	$0.1V+0.86$
Horizontal Closed	
<i>Solid</i>	$HCS.SC.M$
All volumes	$0.05V+0.91$

⁸³⁰ ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

⁸³¹ Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).



<i>Transparent</i>	<i>HCT.SC.M</i>
All volumes	0.06V+0.37

Where V = Association of Home Appliances Manufacturers (AHAM) volume

* 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)).)

$kWhEEdaily_{max}^{832}$ = See table below.

Product Volume (in cubic feet)	Refrigerator ($kWhBASEdaily_{max}$)
Vertical Closed	
<i>Solid</i>	<i>VCS.SC.M*</i>
0 < V < 15	0.022V+0.97
15 ≤ V < 30	0.066V+0.31
30 ≤ V < 50	0.04V+1.09
50 ≤ V	0.024V+1.89
<i>Transparent</i>	<i>VCT.SC.M</i>
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	
<i>Solid or Transparent</i>	<i>HCT.SC.M, HCS.SC.M</i>
All volumes	0.05V+0.28

Where V = Association of Home Appliances Manufacturers (AHAM) volume

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh/HOURS) * CF.$$

Where:

HOURS = Full load hours.

⁸³² ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.



$$\begin{aligned} CF &= 5858. \text{ }^{833} \\ &= 0.772. \text{ }^{834} \end{aligned}$$

= Summer Peak Coincidence Factor for measure.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost ⁸³⁵

The incremental cost for this time of sale measure is assumed to be \$0. ⁸³⁶

Measure Life

The measure life is assumed to be 12 years. ⁸³⁷

Operation and Maintenance Impacts

n/a

⁸³³ Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

⁸³⁴ 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.

⁸³⁵ Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigerator_v3.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum.

⁸³⁶ Energy Star Calculator accessed April 25, 2017, which cites Energy Star research, 2014.

⁸³⁷ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.



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

$$\Delta \text{kWh} = (\text{LOAD} / 12,000) * \text{FEET} * (3.516) / \text{COP} * \text{ESF} * 8,760.$$

$$\Delta \text{kWh} = 346.5 * \text{FEET} / \text{COP}.$$

Where:

<i>LOAD</i>	<i>= average refrigeration load per linear foot of refrigerated case without night covers deployed.</i> <i>= 1,500 Btu/h⁸³⁸ per linear foot.</i>
<i>FEET</i>	<i>= linear (horizontal) feet of covered refrigerated case.</i>
<i>12,000</i>	<i>= conversion factor - Btu per ton cooling.</i>
<i>3.516</i>	<i>= conversion factor – Coefficient of Performance (COP) to kW per ton.</i>

⁸³⁸ 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_Refrigerator.pdf>



<i>COP</i>	<i>= Coefficient of Performance of the refrigerated case. = assume 2.2⁸³⁹, if actual value is unknown.</i>
<i>ESF</i>	<i>= Energy Savings Factor; reflects the percent reduction in refrigeration load due to the deployment of night covers = 9%.⁸⁴⁰</i>
<i>8,760</i>	<i>= assumed annual operating hours of the refrigerated case.</i>

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0^{841}$$

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.⁸⁴²

Measure Life

The expected measure life is assumed to be 5 years.⁸⁴³

Operation and Maintenance Impacts

⁸³⁹ Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.

⁸⁴⁰ 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.

⁸⁴¹ Assumed that the continuous covers are deployed at night; therefore no demand savings occur during the peak period.

⁸⁴² 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008
<http://deerresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip>

⁸⁴³ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.



REGIONAL EVALUATION,
MEASUREMENT & VERIFICATION FORUM

n/a



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.⁸⁴⁴
- $\%ON_{NONE}$ = Effective run time of uncontrolled ASDH.
= assume 90.7%.⁸⁴⁵
- $\%ON_{CONTROL}$ = Effective run time of ASDH with controls.
= assume 58.9% for ON/OFF controls and 42.8% for micropulse controls.⁸⁴⁶
- NUM_{doors} = 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.⁸⁴⁷

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kW_d * WHFd * CF.$$

Where:

- $WHFd$ = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment.
= assume 1.25 for cooler and 1.50 for freezer.
- CF = Summer Peak Coincidence Factor.
= If site specific CFs are unknown, use deemed estimates in the table below.⁸⁴⁸

Control Type	$CF_{refrigerator}$	$CF_{freezer}$
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⁸⁴⁴ Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

⁸⁴⁵ Ibid.

⁸⁴⁶ Ibid.

⁸⁴⁷ 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.

⁸⁴⁸ Ibid.



On/Off Controls	0.25	0.21
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 door⁸⁴⁹. Values include labor costs.

Measure Life

The expected measure life is assumed to be 12 years.⁸⁵⁰

Operation and Maintenance Impacts

n/a

⁸⁴⁹ Navigant. 2015. *Incremental Cost Study Phase Four, Final Report*. Burlington, MA.

⁸⁵⁰ 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

$$\Delta \text{kWh} = \text{kW}_{hp} * \text{HP} * \% \Delta_P * \% \text{ON}_{UC} * \text{HOURS} * \text{WHFe}.$$

Where:

kW_{hp} = ECM connected load kW per horsepower.
= If actual kW_{hp} is unknown, assume 0.758 kW/hp.⁸⁵¹

HP = Horsepower of ECM.
= Actual horsepower of ECM.

⁸⁵¹ 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%.⁸⁵²
- $\% ON_{UC}$ = Effective run time of uncontrolled motors.
= If actual $\% ON_{UC}$ is unknown, assume 97.8%.⁸⁵³
- 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.⁸⁵⁴

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.⁸⁵⁵
- CF = Summer Peak Coincidence Factor.
= If site specific CFs are unknown, use 1.53.⁸⁵⁶

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

⁸⁵² Ibid.

⁸⁵³ Ibid.

⁸⁵⁴ Ibid.

⁸⁵⁵ Ibid.

⁸⁵⁶ 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.⁸⁵⁷

Measure Life

The expected measure life is assumed to be 15 years.⁸⁵⁸

Operation and Maintenance Impacts

n/a

⁸⁵⁷ 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.

⁸⁵⁸ 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

$$\Delta \text{kWh} = \text{kW}_{\text{hp}} * \text{HP} * (\% \text{ON}_{\text{UC}} - \% \text{ON}_{\text{CONTROL}}) * \text{HOURS} * \text{WHFe}$$

Where:



kW_{hp}	<p>= connected load kW per horsepower of motor.</p> <p>= If actual kW_{hp} is unknown, assume 0.758 kW/hp for ECM and 2.088 kW/hp for SP motor.⁸⁵⁹</p>
HP	<p>= Horsepower of ECM or SP motor.</p> <p>= Actual horsepower of ECM or SP motor.</p>
%ON _{UC}	<p>= Effective run time of uncontrolled motor</p> <p>= If actual %ON_{UC} is unknown, assume 97.8%.⁸⁶⁰</p>
%ON _{CONTROL}	<p>= Effective run time of motor with controls.</p> <p>= Assume 63.6% for ON/OFF style controls and 69.2% for multi-speed style controls.⁸⁶¹</p>
HOURS	<p>= Hours of operation.</p> <p>= 8,760.</p>
WHFe	<p>= Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.</p> <p>= assume 1.38 for cooler and 1.76 for freezer applications.⁸⁶²</p>

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kW_{hp} * HP * WHFd * CF$$

Where:

WHFd	<p>= Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.</p> <p>= assume 1.38 for cooler and 1.76 for freezer applications.⁸⁶³</p>
CF	<p>= Summer Peak Coincidence Factor.</p> <p>= If site specific CFs are unknown, use 0.26.⁸⁶⁴</p>

Annual Fossil Fuel Savings Algorithm

n/a

⁸⁵⁹ Cadmus. 2015. *Commercial Refrigeration Loadshape Project*. Lexington, MA.

⁸⁶⁰ Ibid.

⁸⁶¹ Ibid.

⁸⁶² Ibid.

⁸⁶³ Ibid.

⁸⁶⁴ 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.



Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost is \$532 for multispeed controls⁸⁶⁵. Value includes labor costs.

The actual measure installation cost for ON/OFF controls should be used (including materials and labor)⁸⁶⁶.

Measure Life

The expected measure life is assumed to be 10 years.⁸⁶⁷

Operation and Maintenance Impacts

n/a

⁸⁶⁵ Navigant. 2015. *Incremental Cost Study Phase Four, Final Report*. Burlington, MA.

⁸⁶⁶ 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.

⁸⁶⁷ Energy & Resource Solutions (ERS). 2005. *Measure Life Study*: prepared for The Massachusetts Joint Utilities.



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)
= 6,059.⁸⁶⁸*

*kBtu_req (School) = Required annual heating output of school (kBtu)
= 22,191.⁸⁶⁹*

⁸⁶⁸ 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.

⁸⁶⁹ 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.
 EF_{fee} = Energy Factor of Heat Pump domestic water heater.
= 2.0.⁸⁷⁰
 EF_{base} = Energy Factor of baseline domestic water heater.
= 0.904.⁸⁷¹

$\Delta \text{kWh Office}$ = $(6,059 / 3.413) * ((1/0.904) - (1/2.0))$.
= 1076.2 kWh.

$\Delta \text{kWh School}$ = $(22,191 / 3.413) * ((1/0.904) - (1/2.0))$.
= 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:

$$\text{kBtu_req} = \text{GPD} * 8.33 * 1.0 * \text{WaterTempRise} * 365 / 1000.$$

Where:

GDP = Average daily hot water requirements (gallons/day).
= Actual usage (Note: days when the building is unoccupied must be included in the averaging calculation).
 8.33 = Density of water (lb/gallon).
 1.0 = Specific heat of water (Btu/lb-°F).
 WaterTempRise = Difference between average temperature of water delivered to site and water heater setpoint (°F).
 365 = Days per year.

Summer Coincident Peak kW Savings Algorithm

$$\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} * \text{CF}$$

Where:

Hours (Office) = Run hours in office.

⁸⁷⁰ 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

⁸⁷¹ Ibid.



$$= 5885. \text{ }^{872}$$

Hours (School) = Run hours in school.

$$= 2218. \text{ }^{873}$$

CF (Office) = Summer Peak Coincidence Factor for office measure.

$$= 0.630. \text{ }^{874}$$

CF (School) = Summer Peak Coincidence Factor for school measure.

$$= 0.580. \text{ }^{875}$$

$$\Delta \text{kW Office} = (1076.2 / 5885) * 0.630.$$

$$= 0.12 \text{ kW.}$$

$$\Delta \text{kW School} = (3941.4 / 3.413) * 0.580.$$

$$= 1.03 \text{ kW.}$$

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

⁸⁷² Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.

⁸⁷³ Ibid.

⁸⁷⁴ Ibid.

⁸⁷⁵ Ibid.



Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is provided below.⁸⁷⁶

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.⁸⁷⁷

Operation and Maintenance Impacts

n/a

⁸⁷⁶ 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.

⁸⁷⁷ 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

$$\Delta \text{kWh} = \Delta \text{Water} \times \text{HOT\%} \times 8.33 \times (\Delta T) \times (1/\text{EFF}) / 3413.$$

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%. ⁸⁷⁸
8.33	= The energy content of heated water (Btu/gallon/°F).

⁸⁷⁸ 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. ⁸⁷⁹
EFF	= Water heater thermal efficiency. = 0.97. ⁸⁸⁰
3413	= Factor to convert Btu to kwh.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0$$

Annual Fossil Fuel Savings Algorithm

$$\Delta \text{MMBtu} = \Delta \text{Water} \times \text{HOT\%} \times 8.33 \times (\Delta T) \times (1/EFF) \times 10^{-6}$$

Where:

EFF	= Water heater thermal efficiency. = 0.75 ⁸⁸¹ .
10^{-6}	= Factor to convert Btu to MMBtu.

Annual Water Savings Algorithm

$$\Delta \text{Water} = (\text{FLO}_{\text{base}} - \text{FLO}_{\text{eff}}) \times 60 \times \text{HOURS}_{\text{day}} \times 365$$

Where :

ΔWater	= Annual water savings (gal).
FLO_{base}	= The flow rate of the baseline spray nozzle. = 3 gallons per minute.
FLO_{eff}	= The flow rate of the efficient equipment. = 1.6 gallons per minute.
60	= minutes per hour.
365	= days per year.
HOURS	= Hours used per day – depends on facility type as below. ⁸⁸²

⁸⁷⁹ Engineering judgment; assumes typical supply water temperature of 70°F and a hot water storage tank temperature of 140°F.

⁸⁸⁰ Federal Standards.

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/51

⁸⁸¹ IECC 2006. Performance requirement for gas water heaters.

⁸⁸² 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.⁸⁸³

Operation and Maintenance Impacts

n/a

⁸⁸³ 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.



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:⁸⁸⁴

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.

⁸⁸⁴ U.S. EPA. 2015. ENERGY STAR® Program Requirements Product Specification for Clothes Washers Eligibility Criteria Version 7.1



Definition of Efficient Condition

The efficient condition is a clothes washer meeting the ENERGY STAR efficiency criteria presented above.

Annual Energy Savings Algorithm

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{DHW} + \Delta kWh_{DRYER}$$

$$\Delta kWh_{CW} = (kWh_{UNIT, BASE} - kWh_{UNIT, EE}) * \%CW$$

$$\Delta kWh_{DHW} = (kWh_{UNIT, BASE} - kWh_{UNIT, EE}) * \%DHW * DHW_{ELEC}$$

$$\Delta kWh_{DRYER} = [(kWh_{TOTAL, BASE} - kWh_{TOTAL, EE}) - (kWh_{UNIT, BASE} - kWh_{UNIT, EE})] * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE_MOD} * DRYER_{ELEC}$$

$$kWh_{UNIT, i} = kWh_{UNIT_RATED, i} * Ncycles / Ncycles_ref$$

$$kWh_{TOTAL, i} = Capacity / MEF_i * Ncycles$$

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.⁸⁸⁵

$kWh_{UNIT_RATED, EE}$ = Efficient rated unit electricity consumption.
= If actual value unknown, assume 97 kWh/yr.⁸⁸⁶

⁸⁸⁵ 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

⁸⁸⁶ Ibid.



$\%CW$	<p>= Percentage of unit energy consumption used for clothes washer operation.</p> <p>= If unknown, assume 20%.⁸⁸⁷</p>
$\%DHW$	<p>= Percentage of unit energy consumption used for water heating.</p> <p>= If unknown, assume 80%.⁸⁸⁸</p>
DHW_{ELEC}	= 1 if electric water heating; 0 if gas water heating.
MEF_{BASE}	<p>= Modified Energy Factor of baseline unit.</p> <p>= Values provided in table below.</p>
MEF_{EE}	<p>= Modified Energy Factor of efficient unit.</p> <p>= Actual. If unknown assume average values provided below.</p>
Capacity	<p>= Clothes washer capacity (cubic feet).</p> <p>= Actual. If capacity is unknown assume average 3.43 cubic feet.⁸⁸⁹</p>

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	

N_{cycles}	<p>= Number of cycles per year.</p> <p>= If actual value unknown, assume 1,241 for multifamily applications and 2,190 for landromats.⁸⁹⁰</p>
N_{cycles_ref}	<p>= Reference number of cycles per year.</p> <p>= 392.⁸⁹¹</p>
$\%LOADS_{DRYED}$	<p>= Percentage of washer loads dried in machine.</p> <p>= If actual value unknown, assume 100%.</p>
$DRYER_{USAGE}$	= Dryer usage factor.

⁸⁸⁷ Ibid.

⁸⁸⁸ Ibid.

⁸⁸⁹ 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>.

⁸⁹⁰ 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

⁸⁹¹ Ibid.



$$\begin{aligned}
 &= 0.84.^{892} \\
 DRYER_{USAGE_MOD} &= \text{Dryer usage in buildings with dryer and washer} \\
 &= 0.95.^{893} \\
 DRYER_{ELEC} &= 1 \text{ if electric dryer; } 0 \text{ if gas dryer.}
 \end{aligned}$$

Note, utilities may consider whether it is appropriate to claim kWh savings from the reduction in water consumption arising from this measure. The kWh savings would be in relation to the pumping and wastewater treatment. See water savings for characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh / \text{Hours} * CF$$

Where:

$$\begin{aligned}
 \text{Hours} &= \text{Assumed Run hours of Clothes Washer.} \\
 &= 265.^{894} \\
 CF &= \text{Summer Peak Coincidence Factor for measure} \\
 &= 0.029.^{895}
 \end{aligned}$$

Annual Fossil Fuel Savings Algorithm

$$\begin{aligned}
 \Delta MMBtu &= \Delta MMBtu_{DHW} + \Delta MMBtu_{DRYER} \\
 \Delta MMBtu_{DHW} &= (kWh_{UNIT, BASE} - kWh_{UNIT, EE}) * \%DHW / DHW_{EFF} * \\
 &\quad MMBtu_convert * DHW_{GAS} \\
 \Delta MMBtu_{DRYER} &= [(kWh_{TOTAL, BASE} - kWh_{TOTAL, EE}) - (kWh_{UNIT, BASE} - kWh_{UNIT, EE})] * \\
 &\quad MMBtu_convert * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE_MOD} * \\
 &\quad DRYER_{GAS, CORR} * DRYER_{GAS}
 \end{aligned}$$

Where:

⁸⁹² Ibid.

⁸⁹³ Ibid.

⁸⁹⁴ 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.

⁸⁹⁵ Ibid.



$\Delta MMBtu_{DHW}$ = Water heating gas energy savings

$\Delta MMBtu_{DRYER}$ = Dryer gas energy savings

DHW_{EFF} = Gas water heater efficiency.

= If actual unknown, assume 75%.

$MMBtu_convert$ = Conversion factor from kWh to MMBtu.
= 0.003413.

DHW_{GAS} = 1 if gas water heating; 0 if electric water heating.

$DRYER_{GAS,CORR}$ = Gas dryer correction factor; 1.12.⁸⁹⁶

$DRYER_{GAS}$ = 1 if gas dryer; 0 if electric dryer.

Annual Water Savings Algorithm

$$\Delta Water (CCF) = Capacity * (WF_{BASE} - WF_{EE}) * Ncycles / 748$$

Where

WF_{BASE} = Water Factor of baseline clothes washer.
= Values provided below.

WF_{EE} = Water Factor of efficient clothes washer.
= Actual. If unknown assume value provided below.

748 = Conversion factor from gallons to CCF.

Efficiency Level	Water Factor (WF)	
	Front Loading	Top Loading
Federal Standard	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.

$$\Delta kWh_{water}^{897} = 2.07 \text{ kWh/CCF} * \Delta Water (CCF)$$

⁸⁹⁶ 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



Incremental Cost

The lifecycle NPV incremental cost for this time of sale measure is \$200.⁸⁹⁸

Measure Life

The measure life is assumed to be 7 years.⁸⁹⁹

Operation and Maintenance Impacts

n/a

⁸⁹⁷ 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.

⁸⁹⁸ 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.

⁸⁹⁹ 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 devices⁹⁰⁰ when the master load is not in use.

Annual Energy Savings Algorithm

$$\Delta\text{kWh} = 26.9 \text{ kWh}^{901}$$

⁹⁰⁰ 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.

⁹⁰¹ Energy & Resource Solutions. 2013. Emerging Technologies Research Report; Advanced Power Strips for Office Environments prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships.” Assumes savings consistent with the 20W threshold setting for the field research site (of two) demonstrating higher energy savings. ERS noted that the 20 W threshold may be unreliable due to possible inaccuracy of the threshold setting in currently available units. It is assumed that future technology improvements will reduce the significance of this issue. Further, savings from the site with higher average savings was adopted (26.9 kWh versus 4.7 kWh) acknowledging that investigations of APS savings in other jurisdictions have found significantly higher



Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0 \text{ kW}$$

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 \$18⁹⁰².

Measure Life

The measure life is assumed to be 4 years.⁹⁰³

Operation and Maintenance Impacts

n/a

savings. For example, Northwest Power and Conservation Council, Regional Technical Forum. 2011.

"Smart Power Strip Energy Savings Evaluation" found average savings of 145 kWh.

⁹⁰² 2016 Illinois Technical Resource Manual

⁹⁰³ 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.⁹⁰⁴ 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.⁹⁰⁵

Annual Energy Savings Algorithm

$$\text{kWh}_i = (\text{kWh_Cooking}_i + \text{kWh_Idle}_i) \times \text{DAYS}$$

$$\text{kWh_Cooking}_i = \text{LB} \times \text{E}_{\text{FOOD}} / \text{EFF}_i$$

$$\text{kWh_Idle}_i = \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB} / \text{PC}_i)$$

$$\text{kWh}_i = [\text{LB} \times \text{E}_{\text{FOOD}} / \text{EFF}_i + \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB} / \text{PC}_i)] \times \text{DAYS}$$

⁹⁰⁴ 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.

⁹⁰⁵ US EPA. December 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Version 3.0



$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:⁹⁰⁶

- 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.

⁹⁰⁶ 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		Large Vat	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
IDLE (kW)	1.05	0.80	1.35	1.10
EFF	75%	83%	70%	80%
PC	65	70	100	110

Summer Coincident Peak kW Savings Algorithm ⁹⁰⁷

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

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:⁹⁰⁸

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.

⁹⁰⁷ 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.

⁹⁰⁸ 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

Parameter	Standard Size		Large Vat	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
IDLE (MMBtu/h)	0.014	0.009	0.016	0.012
EFF	35%	50%	35%	50%
PC	60	65	100	110

Annual Water Savings Algorithm

n/a

Incremental Cost⁹⁰⁹

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 years⁹¹⁰

Operation and Maintenance Impacts

n/a

⁹⁰⁹ 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>

⁹¹⁰ 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.⁹¹¹

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:*⁹¹²

⁹¹¹ US EPA. August 2003. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers Eligibility Criteria Version 1.2

⁹¹² 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_calcul



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.

[ator.xlsx](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 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 ⁹¹³

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

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: ⁹¹⁴

⁹¹³ 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.

⁹¹⁴ 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

Parameter	No. of Pans	Baseline Model		Energy Efficient Model
		Steam Generator	Boiler Based	All
IDLE (MMBtu)	3	0.018	0.015	0.00625
	4			0.00835
	5			0.01040
	6+			0.01250
EFF	All	18%	15%	38%

Annual Water Savings Algorithm

$$\Delta Water = (GPH_{base} - GPH_{eff}) \times HOURS_{DAY} \times DAYS.$$

Where:⁹¹⁵

GPH_{base} = Water consumption rate (gal/h) of baseline equipment.

⁹¹⁵ 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} = if water consumption rate of baseline equipment is unknown, assume default values from table below.
 = Water consumption rate (gal/h) of efficient equipment.
 = if water consumption rate of efficient equipment is unknown, assume default values from table below.

Parameter	No. of Pans	Baseline Model	Energy Efficient Model		
		All	Steam Generator	Boiler Based	Boilerless
GPH	All	40	15	10	3

Incremental Cost⁹¹⁶

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 years⁹¹⁷

Operation and Maintenance Impacts

n/a

⁹¹⁶ 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>

⁹¹⁷ 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.⁹¹⁸

Annual Energy Savings Algorithm

$$\Delta \text{kWh} = (\text{IDLE}_{\text{base}} - \text{IDLE}_{\text{eff}}) / 1000 \times \text{HOURS}_{\text{DAY}} \times \text{DAYS}$$

Where:⁹¹⁹

- $\text{IDLE}_{\text{base}}$ = 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.

⁹¹⁸ US EPA. April 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0.

⁹¹⁹ 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>



$HOURS_{DAY}$ = average daily operating hours.
= 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 ⁹²⁰

$$\Delta kW = (IDLE_{base} - IDLE_{eff}) / 1000$$

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 ($IDLE_{eff}$)
$0 < VOLUME < 13$	$40 \times VOLUME$	$21.5 \times VOLUME$
$13 \leq VOLUME < 28$	$40 \times VOLUME$	$2.0 \times VOLUME + 254.0$
$28 \leq VOLUME$	$40 \times VOLUME$	$3.8 \times VOLUME + 203.5$

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 ⁹²¹

The incremental cost for a for this time of sale measure ENERGY STAR hot food holding cabinets is assumed to be \$0.

Measure Life

⁹²⁰ 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.

⁹²¹ 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 years⁹²²

Operation and Maintenance Impacts

n/a

⁹²² 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.⁹²³

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:*⁹²⁴

⁹²³ US EPA. January 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles Eligibility Criteria Version 1.2.



<i>i</i>	= either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.
<i>kWh_Cooking_i</i>	= daily cooking energy consumption (kWh).
<i>kWh_Idle_i</i>	= daily idle energy consumption (kWh).
<i>kWh_{base}</i>	= the annual energy usage of the baseline equipment calculated using baseline values.
<i>kWh_{eff}</i>	= the annual energy usage of the efficient equipment calculated using efficient values.
<i>LB</i>	= Pounds of food cooked per day (lb/day) . = if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.
<i>E_{FOOD}</i>	= ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food. = 0.139.
<i>EFF</i>	= Heavy load cooking energy efficiency (%). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
<i>IDLE</i>	= Idle energy rate (kW/ft ²). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
<i>SIZE</i>	= size of the griddle surface (ft ²).
<i>HOURS_{DAY}</i>	= average daily operating hours. = if average daily operating hours are unknown, assume default of 12 hours/day.
<i>PC</i>	= 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.
<i>DAYS</i>	= annual days of operation. = if annual days of operation are unknown, assume default of 365 days.

Efficient Griddle Performance Metrics: Baseline and Efficient Values

⁹²⁴ 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

Summer Coincident Peak kW Savings Algorithm ⁹²⁵

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

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:⁹²⁶

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.

⁹²⁵ 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.

⁹²⁶ 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/ft²).
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

Gas Griddle Performance Metrics: Baseline and Efficient Values

Parameter	Baseline Model	Efficient Model
IDLE (MMBtu/h/ft ²)	0.00350	0.00265
EFF	32%	38%
PC	4.17	7.50

Annual Water Savings Algorithm

n/a

Incremental Cost⁹²⁷

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 years⁹²⁸

Operation and Maintenance Impacts

n/a

⁹²⁷ 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>

⁹²⁸ Ibid.



Commercial Convection Ovens

Unique Measure Code(s): CI_KE_TOS_CONOV_0615

Effective Date: June 2015

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 qualified electric or gas convection oven.⁹²⁹

Annual Energy Savings Algorithm

$$kWh_i = (kWh_Cooking_i + kWh_Idle_i) \times DAYS$$

$$kWh_Cooking_i = LB \times E_{FOOD}/EFF_i$$

$$kWh_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

⁹²⁹ US EPA. January 2014. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.1



Where:⁹³⁰

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 12 hours/day.
$DAYS$	= annual days of operation. = if annual days of operation are unknown, assume default of 365 days.
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.

⁹³⁰ 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>



Electric Convection Oven Performance Metrics: Baseline and Efficient Values⁹³¹

Parameter	Half Size		Full Size	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model
IDLE (kW)	1.03	1.00	2.00	1.60
EFF	68%	71%	65%	71%
PC	45	50	90	90

Summer Coincident Peak kW Savings Algorithm⁹³²

$$\Delta \text{kW} = \Delta \text{kWh} / (\text{HOURS}_{\text{DAY}} \times \text{DAYS})$$

Annual Fossil Fuel Savings Algorithm

$$\text{MMBtu}_i = (\text{MMBtu}_{\text{Cooking}_i} + \text{MMBtu}_{\text{Idle}_i}) \times \text{DAYS}$$

$$\text{MMBtu}_{\text{Cooking}_i} = \text{LB} \times E_{\text{FOOD}} / \text{EFF}_i$$

$$\text{MMBtu}_{\text{Idle}_i} = \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB} / \text{PC}_i)$$

$$\text{MMBtu}_i = [\text{LB} \times E_{\text{FOOD}} / \text{EFF}_i + \text{IDLE}_i \times (\text{HOURS}_{\text{DAY}} - \text{LB} / \text{PC}_i)] \times \text{DAYS}$$

$$\Delta \text{MMBtu} = \text{MMBtu}_{\text{base}} - \text{MMBtu}_{\text{eff}}$$

Where:⁹³³

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.

⁹³¹ Food Service Technology Center (FSTC). Default value from life cycle cost calculator.

<http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php>.

⁹³² 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.

⁹³³ 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>



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 \$0.⁹³⁴

Measure Life

12 years⁹³⁵

Operation and Maintenance Impacts

n/a

⁹³⁴ 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>

⁹³⁵ 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_0615

Effective Date: June 2015

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 qualified electric or gas combination oven.⁹³⁶

Annual Energy Savings Algorithm

$$\text{kWh}_{i,j} = (\text{kWh_Cooking}_{i,j} + \text{kWh_Idle}_{i,j}) \times \text{DAYS}$$

$$\text{kWh_Cooking}_{i,j} = \text{LB} \times E_{\text{FOOD},j} / \text{EFF}_{i,j} \times \text{PCT}_j$$

$$\text{kWh_Idle}_{i,j} = \text{IDLE}_{i,j} \times (\text{HOURS}_{\text{DAY}} - \text{LB} / \text{PC}_{i,j}) \times \text{PCT}_j$$

$$\text{kWh}_{i,j} = [\text{LB} \times E_{\text{FOOD},j} / \text{EFF}_{i,j} + \text{IDLE}_{i,j} \times (\text{HOURS}_{\text{DAY}} - \text{LB} / \text{PC}_{i,j})] \times \text{PCT}_j \times \text{DAYS}$$

$$\text{kWh}_{\text{base}} = \text{kWh}_{\text{base,conv}} + \text{kWh}_{\text{base,steam}}$$

$$\text{kWh}_{\text{eff}} = \text{kWh}_{\text{eff,conv}} + \text{kWh}_{\text{eff,steam}}$$

$$\Delta \text{kWh} = \text{kWh}_{\text{base}} - \text{kWh}_{\text{eff}}$$

⁹³⁶ US EPA. January 2014. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.1



Where:⁹³⁷

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, assume default of 12 hours/day.
$DAYS$	= annual days of operation. = if annual days of operation are unknown, assume default of 365 days.
$E_{FOOD,conv}$	= 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). = see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

⁹³⁷ 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>



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 ⁹³⁸

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

Annual Fossil Fuel Savings

$$MMBtu_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$MMBtu_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$$

$$MMBtu_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j}) \times PCT_j$$

$$MMBtu_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$MMBtu_{base} = kWh_{base,conv} + kWh_{base,steam}$$

$$MMBtu_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

$$\Delta MMBtu = MMBtu_{base} - MMBtu_{eff}$$

⁹³⁸ 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.



Where:⁹³⁹

- $MMBtu_{Cooking_i}$ = 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 convection 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
	>= 15	176	211	210	277

⁹³⁹ 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
	and < 30				
	>= 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 \$0.⁹⁴⁰

Measure Life

12 years⁹⁴¹

Operation and Maintenance Impacts

n/a

⁹⁴⁰ 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>

⁹⁴¹ Ibid.



APPENDIX

A. RETIRED

B. Description of Unique Measure Codes

C. RETIRED

D. Commercial & Industrial Lighting Operating Hours, Coincidence Factors, and Waste Heat Factors



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, Coincidence Factors, and Waste Heat Factors

C&I Interior Lighting Operating Hours by Building Type⁹⁴²

Building Type	Sector	HOURS
Grocery	Large Commercial/Industrial & Small Commercial	7,134
Health	Large Commercial/Industrial & Small Commercial	3,909
Office	Large Commercial/Industrial	2,969
	Small Commercial	2,950
Other	Large Commercial/Industrial & Small Commercial	4,573
Retail	Large Commercial/Industrial	4,920
	Small Commercial	4,926
School	Large Commercial/Industrial & Small Commercial	2,575
Warehouse/ Industrial	Large Commercial/Industrial	4,116
	Small Commercial	3,799
Unknown ⁹⁴³	Large Commercial/Industrial	2,575

Note: 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.

⁹⁴² 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.

⁹⁴³ To encourage the use of building type-specific values, the assumed lighting operating hours for unknown building types have been set equal to the lowest value from the table.



C&I Interior Lighting Coincidence Factors by Building Type⁹⁴⁴

Building Type	Sector	CF _{SSP}	CF _{PJM}
Grocery	Large Commercial/Industrial & Small Commercial	0.96	0.96
Health	Large Commercial/Industrial & Small Commercial	0.8	0.79
Office	Large Commercial/Industrial	0.7	0.69
	Small Commercial	0.67	0.67
Other	Large Commercial/Industrial & Small Commercial	0.66	0.67
Retail	Large Commercial/Industrial	0.96	0.94
	Small Commercial	0.86	0.85
School	Large Commercial/Industrial & Small Commercial	0.50	0.42 ⁹⁴⁵
Warehouse/ Industrial	Large Commercial/Industrial	0.7	0.72
	Small Commercial	0.68	0.7
Unknown ⁹⁴⁶	Large Commercial/Industrial	0.50	0.42

Note(s): 1) CF_{PJM} refers to the PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm). CF_{SSP} refers to Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday). 2) 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.

⁹⁴⁴ 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.

⁹⁴⁵ C&I Lighting Load Shape Project FINAL Report, KEMA, 2011.

⁹⁴⁶ To encourage the use of building type-specific values, the assumed lighting coincidence factors for unknown building types have been set equal to the lowest values from the table.



Waste Heat Factors for C&I Lighting – Known HVAC Types⁹⁴⁷

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 ⁹⁴⁸
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
	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

⁹⁴⁷ 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.

⁹⁴⁸ 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 ⁹⁴⁸
Maryland, Potomac Edison	Other	1.34	1.32	1.08	0.82	0.93	0.74
	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.