Northeast Energy Efficiency Partnerships

MID-ATLANTIC
TECHNICAL REFERENCE MANUAL
VERSION 5.0

Final Draft

June 2015

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.

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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VERSION 5.0

A Project of the Regional Evaluation, Measurement and Verification Forum

June 2015

Prepared by Shelter Analytics

Facilitated and Managed by Northeast Energy Efficiency Partnerships

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**Measure was updated for this version of the TRM*

***Measure is newly added to this version of the TRM*

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: http://www.neep.org/initiatives/emv-forum.

Acknowledgements

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Subcommittee for the Mid-Atlantic TRM

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INTRODUCTION

This 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 algorithms[1] for calculating:

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

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

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

The TRM is intended to be a flexible and living document. To that end, NEEP, the project sponsors and the TRM authors all expect it to be periodically updated 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. Initial recommendations for a process by which updates could occur are provided in Appendix B.

Context

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

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 fifth generation (fourth up-date) 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://www.neep.org/emv-forum-glossary-terms-and-acronyms. It is important to note that because the TRM was developed on a parallel schedule with the EMV Forum Product A2 (Common Methods Project), draft A2 materials contributed to the research for the TRM, for measures which were common to both Forum projects (specifically residential and commercial lighting measures, residential central and commercial unitary air conditioning, and variable frequency drives).

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 (see the end of this Introduction for a list of subcommittee members). 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 CFLs, T8s or super-T8s, 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 deemed savings).

Measures are selected on the basis of projected or expected savings from program data by measure type provided by Baltimore Gas and Electric, 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. two different efficiency tiers for room air conditioners). 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 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. In addition, such variables may be different in the mid-Atlantic region than in other jurisdictions. 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 assumptions or assumption 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 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 accessible, 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 well 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 standards PJM requires, once sponsors have gained additional experience with the capacity market.

- Expected timelines required to implement the TRM protocols.

- Processes stakeholders envision for conducting annual reviews of utility program savings as well as program evaluations, and therefore what time frame for 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:

- The TRM clearly identifies whether the measure impacts pertain to “retrofit”, “time of sale”,[2] or “early retirement” program designs.
- 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 assumption. 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 assumptions” – 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

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[2] In some jurisdictions, this is called “replace on burn-out”. We use the term “time of sale” because not all new equipment purchases take place when an older existing piece of equipment reaches the end of its life.

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. For example, data from a BG&E metering study of residential central air conditioners was used to estimate both full load hours and system peak coincidence factors. However, a number of assumptions – including assumptions regarding peak coincidence factors – are based on New York and/or New England sources. While this information is not perfectly transferable, due to differences in definitions of peak periods as well as geography and 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 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 interaction 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. While they were beyond the scope of this TRM, it is recommended that a future version of the TRM may include the baseline specifications for any whole-building efficiency measures.
- 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.
- The TRM anticipates the effects of changes in efficiency standards for some measures, specifically CFLs and motors.

The following table outlines the terms used to describe programs with respect to when and how a measure is implemented. 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:

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[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://www.neep.org/file/1010/download?token=XDUhN8Aq (download).

[4] They are captured only for lighting measures.

Program	Attributes
Time of Sale (TOS)	Definition: A program in which the customer is incented to purchase or install higher efficiency equipment than if the program had not existed. This may include retail rebate (coupon) programs, upstream buydown programs, online store programs, contractor based programs, or CFL giveaways as examples. Also applies to End of Life Baseline = New equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: CFL rebate
New Construction (NC)	Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices. Baseline = Building code or federal standards. Efficient Case = The program’s level of building specification Example: Building shell and mechanical measures
Retrofit (RF)	Definition: A program that *upgrades* existing equipment before the end of its useful life. Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure’s life. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Air sealing and insulation
Early Replacement (EREP)	Definition: A program that *replaces* existing equipment before the end of its expected life. Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the expected life of the existing equipment is over. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Refrigerators, freezers
Early Retirement (ERET)	Definition: A program that *retires* duplicative equipment before its expected life is over. Baseline = The existing equipment, which is retired and not replaced. Efficient Case = Zero because the unit is retired. Example: Appliance recycling
Direct Install (DI)	Definition: A program where measures are installed during a site visit. Baseline = Existing equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Lighting and low-flow hot water measures

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

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

RESIDENTIAL MARKET SECTOR

Lighting End Use

General Purpose CFL Screw base, Residential*

Unique Measure Code(s): RS_LT_TOS_CFLSCR_0415

Effective Date: June 2015
End Date: TBD

Measure Description

This measure characterizes the installation of a general purpose compact fluorescent light bulb (CFL) in place of an incandescent bulb. The measure provides assumptions for two implementation strategies (Time of Sale/Retail[5] and Direct Install), and for two markets (Residential and Multi-Family).

This characterization is for a general purpose screw based CFL bulb (A-lamps), and not a specialty bulb (e.g. reflector (PAR) lamps, globes, candelabras, 3-ways etc).

Definition of Baseline Condition

The baseline is the installation of an incandescent/halogen light bulb meeting the standards described in the Energy and Independence and Security Act of 2007[6].

Definition of Efficient Condition

The efficient condition is the installation of a compact fluorescent light bulb.

Annual Energy Savings Algorithm

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

Where:

WattsBase = Based on lumens of CFL bulb[7]:

---

[5] The utilities might consider evaluating what percentage of retail sales end up in commercial locations, and apply the commercial CFL assumptions to that portion. In the absence of such data it is appropriate to use the Residential assumptions for all retail sales since they will represent a significant majority and result in an appropriately conservative estimate.

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

[7] Base wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1;

Minimum Lumens	Maximum Lumens	$\text{Watts}_{\text{Base}}$
4000	6000	300
3001	3999	200
2550	3000	150
2000	2549	125
1600	1999	72
1100	1599	53
800	1099	43
450	799	29
250	449	25

WattsEE = Actual wattage of CFL purchased / installed

ISR = *In Service Rate or percentage of units rebated that are installed and operational.*

Program	In Service Rate (ISR)
Time of Sale (Retail)	0.88[8]
Direct Install	0.82[9]

HOURS = *Average hours of use per year*

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http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

[8] Starting with a first year ISR of 0.82 (based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015) and a lifetime ISR of 0.97 (from Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009"), and assuming 43% of the remaining 15% not installed in the first year replace incandescents (24 out of 56 respondents not purchased as spares; Nexus Market Research, RLW Analytics, October 2004; "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs", table 6-7). ISR is therefore calculated as 0.82 + (0.43*0.15) = 0.88. See MidAtlantic Lighting adjustments and O&M_042015.xls for calculation.

[9] Assumption is based on the EmPOWER _EY5 Res Lighting Results Memo_20Jan2015 DRAFT discussed above, but not adjusted upwards since those people removing bulbs after being installed in Direct Install program are likely to do so because they dislike them, not to use as replacements. Only evaluation we are aware of specifically for Direct Install installation (and persistence) rates is Megdal & Associates, 2003; "2002/2003 Impact Evaluation of LIPA's Clean Energy Initiative REAP Program", which estimated 81%.

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	2.46	898[10]
Multi Family Common Areas	16.3	5,950[11]
Exterior	4.5	1,643[12]
Unknown[13]	2.46	898

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

	$WHFe_{Cool}$
Building with cooling	1.12[14]
Building without cooling or exterior	1.0
Unknown	1.09[15]

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

= 1 - ((HF / ηHeat) * %ElecHeat)

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[10] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 14.

[11] Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Wisconsin's 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.

[12] 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://library.cee1.org/content/impact-evaluation-massachusetts-rhode-island-and-vermont-2003-residential-lighting-programs

[13] For programs where the installation location is unknown (e.g. upstream lighting programs) the assumption is set conservatively to assume an interior residential bulb.

[14] The value is estimated at 1.12 (calculated as 1 + (0.33 / 2.8)). 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 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-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), converted to COP = EER/3.412 = 2.8COP).

[15] The value is estimated at 1.09 (calculated as 1 + (0.78*(0.33 / 2.8)). Based on assumption that 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

If unknown assume 0.894[16]

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[17] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[18]:

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	1.67[19]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[20]

Illustrative examples – do not use as default assumption

A 13W, 850 lumen standard CFL bulb is purchased and installed in an unknown location:

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[16] Calculated using defaults; 1-((0.47/1.67) * 0.375) = 0.894

[17] 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.

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

[19] 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.

[20] Based on KEMA baseline study for Maryland.

$$\Delta kWh = ((43-13)/1000) * 0.88 * 898 * (0.894 + (1.09-1))$$

$$= 23.3\ kWh$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

	WHFd
Building with cooling	*1.24*[21]
Building without cooling or exterior	*1.0*
Unknown	*1.18*[22]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082[23]
	PJM CF	0.084[24]
Multi Family Common Areas	PJM CF	0.43[25]
Exterior	PJM CF	0.018[26]
Unknown	Utility Peak CF	0.082
	PJM CF	0.084

Illustrative examples – do not use as default assumption

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[21] The value is estimated at 1.24 (calculated as 1 + (0.66 / 2.8)). 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).

[22] The value is estimated at 1.18 (calculated as 1 + (0.78 * 0.66 / 2.8)).

[23] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 16.

[24] Ibid.

[25] 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'.

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

A 13W, 850 lumen CFL bulb is purchased and installed in an unknown location:

ΔkW_{PJM} = ((43-13) / 1000) * 0.88 * 1.18 * 0.084

= 0.0026 kW

Annual Fossil Fuel Savings Algorithm

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

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

Where:

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

= *47%*[27] *for interior or unknown location*

= *0% for exterior or unheated location*

0.003412 =*Converts kWh to MMBtu*

ηHeat = *Efficiency of heating system*

=*72%*[28]

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

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[29]

Illustrative examples – do not use as default assumption

A 13W, 780 CFL lumen bulb is purchased and installed in an unknown location:

ΔMMBtuPenalty = - (((43-13)/1000) * 0.88 * 898 * 0.47 * 0.003412/0.72) * 0.625

= - 0.033 MMBtu

---

[27] 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.

[28] 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/

[29] Based on KEMA baseline study for Maryland.

Annual Water Savings Algorithm

n/a

Incremental Cost

For the Retail (Time of Sale) measure, the incremental capital cost is $1.80 from June 2014[30].

For the Direct Install measure, the full cost of $3.20[31] per bulb should be used plus $5 labor[32] for a total measure cost of $8.20 per lamp.

Measure Life

The measure life is assumed to be:

Installation Location	Measure Life
Residential interior and in-unit Multi Family	5.0[33]
Multi Family Common Areas	1.7[34]
Exterior	4.9[35]
Unknown	5.0

Operation and Maintenance Impacts

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[30] Based on incremental costs for 60W equivalent (dominant bulb) from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

[31] Ibid. Based on 15W CFL,

[32] Assumption based on 15 minutes (including portion of travel time) and $20 per hour.

[33] Calculated starting with an average observed life (5.2 years) of compact fluorescent bulbs with rated life of 8000 hours (8000 hours is the average rated life of ENERGY STAR bulbs (http://www.energystar.gov/index.cfm?c=cfls.pr_crit_cfls)). Observed life is based on Jump et al “Welcome to the Dark Side: The Effect of Switching on CFL Measure Life” and is due to increased on/off switching. The 5.2 years is adjusted upwards due to the assumption that 57% of the 9% not installed in the first year eventually replace CFLs (based on 32 out of 56 respondents purchased as spares; Nexus Market Research, RLW Analytics, October 2004; “Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs”, table 6-4). Measure life is therefore calculated as (5.2 + (((0.57 * 0.09)/0.92) *5.2) = 5.5 years.
Note, a provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline. Therefore after 2014 the measure life will have to be reduced each year to account for the number of years remaining to 2020.[33]

[34] Assumed rated life of 10,000 hours due to lower switching (10000/5950 = 1.7).

[35] Assumed rated life of 8,000 hours due to higher switching and use outside (8000/1643 = 4.9)

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic Lighting adjustments and O&M_042015.xls). The key assumptions used in this calculation are documented below:

	Standard Incandescent	Efficient Incandescent
Replacement Cost	$0.50	$1.40[36]
Component Life[37] (years) Residential interior, in-unit Multi Family or unknown	1.1[38]	1.1[39]
Multi Family Common Areas	0.17	0.17
Exterior	0.60	0.60

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below[40]:

Residential interior and in-unit Multi Family

Year	NPV of baseline Replacement Costs
2015	$3.83
2016	$2.94
2017	$2.01

Multi Family Common Areas

Year	NPV of baseline Replacement Costs

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[36] Based on for 60W EISA equivalent (dominant bulb) from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.

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

[38] Assumes rated life of incandescent bulb of 1000 hours.

[39] The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, Optimal Energy and confirmed by N. Horowitz at NRDC) so the lifetime of these EISA qualified bulbs is assumed to be 1000 hours.

[40] Note, these values have been adjusted by the appropriate In Service Rate – the Time of Sale assumption (0.92) is used for the Residential interior and multi-family in unit, the Direct Install assumption (0.88) for the remaining categories. The discount rate used for these calculations is 5.0%. See 'MidAtlantic Lighting adjustments and O&M_042015' for more information.

2015	$5.60
2016	$5.60
2017	$5.60

Exterior

Year	NPV of baseline Replacement Costs
2015	$5.65
2016	$5.65
2017	$4.32

Specialty CFLs, Residential*

Unique Measure Code(s): RS_LT_TOS_SPECCFL_0415

Effective Date: June 2015
End Date: TBD

Measure Description

An ENERGY STAR qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb. Specialty bulbs defined in this characterization are exempt of the EISA 2007 standard and include the following bulb types: three-way, plant light, daylight bulb, bug light, post light, globes G40, candelabra base, vibration service bulb, decorative candle with medium or intermediate base, shatter resistant, reflector (note that the exemption on reflector bulbs is expected to expire in 2014 for the following wattage and bulb types: 45 W (R20 and BR 19); 50W (R30, ER 30, BR 40, and ER 40); 65W (BR30, BR40, and ER 44)).

The measure provides assumptions for two implementation strategies (Time of Sale/Retail[41] and Direct Install), and for two markets (Residential and Multi-Family).

Definition of Baseline Condition

The baseline condition is a specialty incandescent light bulb.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified specialty CFL bulb as defined above that is exempt from EISA 2007.

Annual Energy Savings Algorithm

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

Where:

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[41] The utilities might consider evaluating what percentage of retail sales end up in commercial locations, and apply the commercial CFL assumptions to that portion. In the absence of such data it is appropriate to use the Residential assumptions for all retail sales since they will represent a significant majority and result in an appropriately conservative estimate.

WattsBase = If actual CFL lumens is known – find the equivalent baseline wattage from the table below[42]*; use 61.7W if unknown*[43]

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
3-Way	250	449	25
	450	799	40
	800	1099	60
	1100	1599	75
	1600	1999	100
	2000	2549	125
	2550	2999	150
Globe (medium and intermediate bases less than 750 lumens)	90	179	10
	180	249	15
	250	349	25
	350	749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10
	90	149	15
	150	299	25
	300	749	40
Globe (candelabra bases less than 1050 lumens)	90	179	10
	180	249	15
	250	349	25
	350	499	40
	500	1049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10
	90	149	15
	150	299	25
	300	499	40
	500	1049	60
Reflector with medium screw bases w/ diameter <=2.25"	400	449	40
	450	499	45
	500	649	50
	650	1199	65
	640	739	40

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

[43] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)	740	849	45
	850	1179	50
	1180	1419	65
	1420	1789	75
	1790	2049	90
	2050	2579	100
	2580	3429	120
	3430	4270	150
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26'' and ≤ 2.5" (*see exceptions below)	540	629	40
	630	719	45
	720	999	50
	1000	1199	65
	1200	1519	75
	1520	1729	90
	1730	2189	100
	2190	2899	120
	2900	3850	150
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649-1179[44]	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399-639[45]	30

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[46]

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[44] The upper bounds for these categories depends on the lower bound of the next higher wattage, which varies by bulb type.

[45] As above.

[46] An Illinois evaluation (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-5/31/2010) Evaluation Report: Residential Energy Star ® Lighting http://www2.epa.gov/sites/production/files/2013-12/documents/cee_eval_comedappliancerecyclingpy2evaluationreport2010.pdf) reported 13-17W as the most common specialty CFL wattage (69% of program bulbs). 2009 California data also reported an average CFL wattage of 15.5 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program, Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009).

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

Program	In Service Rate (ISR)
Time of Sale (Retail)	0.86[47]
Direct Install	0.82[48]

HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential and in-unit Multi Family	2.46	898[49]
Multi Family Common Areas	16.3	5,950[50]
Exterior	4.5	1,643[51]
Unknown[52]	2.46	898

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

	$WHFe_{Cool}$

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[47] Starting with a first year ISR of 0.82 (based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015) and a lifetime ISR of 0.97 (from Nexus Market Research, RLW Analytics and GDS Associates study; "New England Residential Lighting Markdown Impact Evaluation, January 20, 2009"), and assuming 43% of the remaining 9% not installed in the first year replace incandescents (24 out of 56 respondents not purchased as spares; Nexus Market Research, RLW Analytics, October 2004; "Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs", table 6-7). ISR is therefore calculated as 0.82 + (0.43*0.09) = 0.86.

[48] Assumption is based on the EmPOWER _EY5 Res Lighting Results Memo_20Jan2015 DRAFT discussed above, but not adjusted upwards since those people removing bulbs after being installed in Direct Install program are likely to do so because they dislike them, not to use as replacements. Only evaluation we are aware of specifically for Direct Install installation (and persistence) rates is Megdal & Associates, 2003; "2002/2003 Impact Evaluation of LIPA's Clean Energy Initiative REAP Program", which estimated 81%.

[49] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 14.

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

[51] 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://library.cee1.org/sites/default/files/library/1308/485.pdf

[52] For programs where the installation location is unknown (e.g. upstream lighting programs) the assumption is set conservatively to assume an interior residential bulb.

Building with cooling	1.12[53]
Building without cooling or exterior	1.0
Unknown	1.09[54]

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

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.894[55]

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[56] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[57]*:*

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

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[53] The value is estimated at 1.12 (calculated as 1 + (0.33 / 2.8)). 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 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-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), converted to COP = EER/3.412 = 2.8COP).

[54] The value is estimated at 1.09 (calculated as 1 + (0.78*(0.33 / 2.8)). Based on assumption that 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[55] Calculated using defaults; 1+ ((0.47/1.67) * 0.375) = 0.894

[56] 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.

[57] 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.

Unknown	N/A	N/A	1.67[58]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[59]

Illustrative example – do not use as default assumption

An 800 lumen 15W Globe CFL is purchased and installed in an unknown location:

ΔkWh = ((60 - 15) / 1000) * 0.86 * 898 * (0.894 + (1.09 – 1))

= 34.2 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((WattsBase - WattsEE) /1000) * ISR * WHFd * CF

Where:

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

	WHFd
Building with cooling	*1.24*[60]
Building without cooling or exterior	1.0
Unknown	*1.18*[61]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Type	Coincidence Factor CF

---

[58] 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.

[59] Based on KEMA baseline study for Maryland.

[60] The value is estimated at 1.24 (calculated as 1 + (0.66 / 2.8)). 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).

[61] The value is estimated at 1.18 (calculated as 1 + (0.78 * 0.66 / 2.8)).

Residential interior and in-unit Multi Family	Utility Peak CF	0.082[62]
	PJM CF	0.084[63]
Multi Family Common Areas	PJM CF	0.43[64]
Exterior	PJM CF	0.018[65]
Unknown	Utility Peak CF	0.082
	PJM CF	0.084

Illustrative example – do not use as default assumption:
An 800 lumen 15W Globe CFL is purchased and installed in an unknown location:

$$\Delta kW_{PJM} = ((60 - 15) / 1000) * 0.86 * 1.18 * 0.084$$

$$= 0.0038 \text{ kW}$$

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[66]):

$$\Delta MMBtuPenalty^{67} = - ((((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.003412) / \eta Heat) * \%FossilHeat$$

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[68] *for interior or unknown location*
= *0% for exterior or unheated location*

0.003412 =*Converts kWh to MMBtu*

ηHeat = *Efficiency of heating system*

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[62] Based on Navigant Consulting “EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study.” April 10, 2015, page 16.

[63] Ibid.

[64] 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’.

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

[66] Based on KEMA baseline study for Maryland.

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

[68] 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.

=72%[69]

%FossilHeat = Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[70]

Illustrative example – do not use as default assumption
An 800 lumen 15W Globe CFL is purchased and installed in a home with 75% AFUE gas furnace:

ΔMMBtuPenalty = - (((60 – 15)/1000) * 0.86 * 898 * 0.47 * 0.003412/0.75) * 1.0

= - 0.097 MMBtu

If home heating fuel is unknown:

ΔMMBtuPenalty = - (((60 - 15)/1000) * 0.86 * 1100 * 0.47 * 0.003412/0.72) * 0.625

= - 0.074 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $3.80[71].

For the Direct Install measure, the full cost of $8.20 should be used plus $5 labor[72] for a total measure cost of $13.20 per lamp.

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[69] 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).

[70] Based on KEMA baseline study for Maryland.

[71] Based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

[72] Assumption based on 15 minutes (including portion of travel time) and $20 per hour.

Measure Life

The expected measure life is assumed to be:

Installation Location	Measure Life
Residential interior and in-unit Multi Family	6.8[73]
Multi Family Common Areas	1.7[74]
Exterior	4.9[75]
Unknown	6.8

Operation and Maintenance Impacts

Life of the baseline bulb is assumed to be 1.1 years for Residential interior and in-unit Multi Family, 0.17 year for Multi Family common areas and 0.6 year for exterior[76]; baseline replacement cost is assumed to be $4.40[77].

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[73] The assumed measure life for the specialty bulb measure characterization was reported in "Residential Lighting Measure Life Study", Nexus Market Research, June 4, 2008 (measure life for markdown bulbs). Measure life estimate does not distinguish between equipment life and measure persistence. Measure life includes products that were installed and operated until failure (i.e., equipment life) as well as those that were retired early and permanently removed from service for any reason, be it early failure, breakage, or the respondent not liking the product (i.e., measure persistence).

[74] Assumed rated life of 10,000 hours due to lower switching (10000/5950 = 1.7).

[75] Assumed rated life of 8,000 hours due to higher switching and use outside (8000/1643 = 4.9)

[76] Assuming 1000 hour rated life for incandescent bulb divided by the hours of use assumption.

[77] Based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

Hardwired CFL Fixtures (Interior)*

Unique Measure Code(s): RS_LT_RTR_CFLFIN_0415 and RS_LT_INS_CFLIN_0415

Effective Date: June 2015
End Date: TBD

Measure Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based (including the GU-24 base) compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either retrofit or new installation, and for two markets (Residential and Multi-Family).

Definition of Baseline Condition

The baseline condition is a standard incandescent/halogen interior light fixture meeting the standards described in the Energy and Independence and Security Act of 2007[78].

Definition of Efficient Condition

The efficient condition is an ENERGY STAR lighting interior fixture for pin-based compact fluorescent lamps.

Annual Energy Savings Algorithm

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

Where:

WattsBase = Based on lumens of CFL bulb[79]:

Minimum Lumens	Maximum Lumens	$Watts_{Base}$
4000	6000	300
3001	3999	200

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

[79] Base wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1; http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

Minimum Lumens	Maximum Lumens	$Watts_{Base}$
2550	3000	150
2000	2549	125
1600	1999	72
1100	1599	53
800	1099	43
450	799	29
250	449	25

#lamps = *Number of lamps in fixture. If unknown, assume 1.*

ISR = *In Service Rate or percentage of units rebated that get installed.*
=0.95 [80]

HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	2.46	898[81]
Multi Family Common Areas	16.3	5,950[82]
Unknown	3.0	1,100

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

	$WHFe_{Cool}$
Building with cooling	1.12[83]

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[80] Based on Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004, p. 42 (Table 4-7).

[81] Based on Navigant Consulting “EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study.” April 10, 2015, page 14.

[82] 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.

[83] The value is estimated at 1.12 (calculated as 1 + (0.33 / 2.8)). 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 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003); A

Building without cooling or exterior	1.0
Unknown	1.09[84]

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

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.894[85]

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

= *47%*[86] *for interior or unknown location*

= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*

= *actual. If not available use*[87]*:*

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	1.67[88]

Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

[84] The value is estimated at 1.09 (calculated as 1 + (0.78*(0.33 / 2.8)). Based on assumption that 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[85] Calculated using defaults; 1+ ((0.47/1.67) * 0.375) = 0.894

[86] 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.

[87] 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.

[88] 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.

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[89]

Illustrative example – do not use as default assumption
A 3 x 11W, 600 lumen fixture is purchased and installed in an unknown location:

$$\Delta kWh = (3 * ((29-11)/1000)) * 0.95 * 898 * (0.894 + (1.09 - 1))$$

$$= 45 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

	WHFd
Building with cooling	*1.24*[90]
Building without cooling or exterior	1.0
Unknown	*1.18*[91]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082[92]
	PJM CF	0.084[93]

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[89] Based on KEMA baseline study for Maryland.

[90] The value is estimated at 1.24 (calculated as 1 + (0.66 / 2.8)). 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).

[91] The value is estimated at 1.18 (calculated as 1 + (0.78 * 0.66 / 2.8)).

[92] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 16.

[93] Ibid.

Multi Family Common Areas	PJM CF	0.43[94]
Unknown	Utility Peak CF	0.082
	PJM CF	0.084

Illustrative example – do not use as default assumption

A 3 x 11W, 600 lumen lamp fixture is purchased and installed in an unknown location:

$$\Delta kW_{PJM} = (3 * ((29-11) / 1000)) * 0.95 * 1.18 * 0.084$$

$$= 0.0051 \text{ kW}$$

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[95]):

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

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[96] *for interior or unknown location*
= *0% for exterior or unheated location*

0.003412 =*Converts kWh to MMBtu*

ηHeat = *Efficiency of heating system*
=*72%*[97]

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

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%

---

[94] 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'.

[95] Based on KEMA baseline study for Maryland.

[96] 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.

[97] 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).

Unknown	62.5%[98]

Illustrative example – do not use as default assumption
A 3 x 11W, 600 lumen lamp fixture is purchased and installed in an unknown location:

$$\Delta MMBtuPenalty = - (((3 * (29-11)/1000)) * 0.95 * 898 * 0.47 * 0.003412/0.72) * 0.625$$

$$= - 0.064 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an interior fixture is assumed to be $32[99].

Measure Life

An additional provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline.

The measure life of an interior fixture[100] will therefore need to be reduced each year and be equal to the remaining number of years before 2020, i.e. for installations in 2015 the measure life should be 5 years, for installations in 2016 the measure life should be 4 years etc.

Operation and Maintenance Impacts

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic Lighting adjustments and O&M_042015.xls). The key assumptions used in this calculation are documented below:

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[98] Based on KEMA baseline study for Maryland.

[99] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/LightingCalculator.xlsx?b299-55ae&b299-55ae)

[100] 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) gives 20 years for an interior fluorescent fixture.

	Baseline		Efficient
	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$1.40[101]	$3.20[102]
Component Life[103] (years) Residential interior, in-unit Multi Family or unknown	1.1[104]	1.1[105]	8.9[106]
Multi Family Common Areas	0.17	0.17	1.34

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below[107]:

Residential interior, in-unit Multi Family or unknown

Year	NPV of baseline Replacement Costs
2015	$4.24
2016	$3.25
2017	$2.22

Multi Family Common Areas

Year	NPV of baseline Replacement Costs
2015	$26.63

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[101] Based on Northeast Regional Residential Lighting Strategy (RLS) report, prepared by EFG, D&R International, Ecova and Optimal Energy.

[102] Ibid.

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

[104] Assumes rated life of incandescent bulb of 1000 hours (simplified to 1 year for calculation).

[105] The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard, so the lifetime of these EISA qualified bulbs is assumed to be 1000 hours.

[106] Assumes 8000 hours rated life for CFL (8000 hours is the average rated life of ENERGY STAR bulbs http://www.energystar.gov/index.cfm?c=lamps.pr_crit_lamps

[107] Note, these values have been adjusted by the appropriate In Service Rate.

Year	NPV of baseline Replacement Costs
2016	$21.98
2017	$17.09

Hardwired CFL Fixtures (Exterior)*

Unique Measure Code(s): RS_LT_RTR_CFLFEX_0415 and RS_LT_INS_CFLFEX_0415
Effective Date: June 2015
End Date: TBD

Measure Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an exterior residential setting. This measure could relate to either retrofit or new installation, and for two markets (Residential and Multi-Family).

Definition of Baseline Condition

The baseline condition is a standard incandescent/halogen exterior light fixture meeting the standards described in the Energy and Independence and Security Act of 2007[108].

Definition of Efficient Condition

The efficient condition is an ENERGY STAR lighting exterior fixture for pin-based compact fluorescent lamps.

Annual Energy Savings Algorithm

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

Where:

WattsBase = Based on lumens of CFL bulb[109]:

Minimum Lumens	Maximum Lumens	WattsBase
4000	6000	300
3001	3999	200

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

[109] Base wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1; http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

Minimum Lumens	Maximum Lumens	WattsBase
2550	3000	150
2000	2549	125
1600	1999	72
1100	1599	53
800	1099	43
450	799	29
250	449	25

#lamps = *Number of lamps in fixture. If unknown, assume 1.*

ISR = *In Service Rate or percentage of units rebated that get installed*
= *0.87* [110]

HOURS = *Average hours of use per year*
= *1643 (4.5 hrs per day)*[111]

Illustrative example – do not use as default assumption
A 2 x 23W, 1600 lumen fixture is purchased and installed in an unknown location:

$$\Delta kWh = (2 * ((72-23)/1000)) * 0.87 * 1643$$

$$= 138\ kWh$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0.018* [112]

---

[110] Consistent with Efficiency Vermont and CT Energy Efficiency Fund; based on Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 42 (Table 4-7).

[111] Updated results from above study, presented in 2005 memo; http://publicservice.vermont.gov/energy/ee_files/efficiency/eval/marivtfinalresultsmemodelivered.pdf

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

Illustrative example – do not use as default assumption
A 2 x 23W, 1600 lumen lamp fixture is purchased and installed in an unknown location:

$$\Delta kW = (2^* (72-23) / 1000) * 0.87 * 0.018$$

$$= 0.0015 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an exterior fixture is assumed to be $17[113].

Measure Life

An additional provision in the Energy Independence and Security Act of 2007 requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the CFL baseline.

The measure life of an exterior fixture[114] will therefore need to be reduced each year and be equal to the remaining number of years before 2020, i.e. for installations in 2010 the measure life should be 10 years, for installations in 2011 the measure life should be 9 years etc.

Operation and Maintenance Impacts

In order to account for the shift in baseline due to the Federal Legislation discussed above, the levelized baseline replacement cost over the lifetime of the CFL is calculated (see MidAtlantic Lighting adjustments and O&M_042015.xls). The key assumptions used in this calculation are documented below:

	Baseline	Efficient

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[113] ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixture (http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_savings)

[114] 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) gives 15 years for an exterior fluorescent fixture.

	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$1.40[115]	$3.20[116]
Component Life (years) (based on lamp life / assumed annual run hours)	0.6[117]	0.6[118]	4.9[119]

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below:

Year	NPV of baseline Replacement Costs[120]
2015	$8.01
2016	$6.34
2017	$4.59

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[115] Based on Northeast Regional Residential Lighting Strategy (RLS) report, prepared by EFG, D&R International, Ecova and Optimal Energy.

[116] Ibid.

[117] Assumes rated life of incandescent bulb of 1000 hours.

[118] The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard ,so the lifetime of these EISA qualified bulbs is assumed to be 1000 hours.

[119] Assumes rated life of 8000 hours.

[120] Note, these values have been adjusted by the appropriate In Service Rate.

Solid State Lighting (LED) Recessed Downlight Luminaire*

Unique Measure Code: RS_LT_TOS_SSLDWN_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight luminaire in place of an incandescent downlight lamp (i.e. time of sale). The SSL downlight should meet the ENERGY STAR Specification for Solid State Luminaires[121]. 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. They currently are *not* subject to EISA regulations and so this characterization does not include the baseline shift provided in other lighting measures.

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 BR-type incandescent downlight light bulb.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

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

Where:

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[121] ENERGY STAR specification can be viewed here: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/SSL_FinalCriteria.pdf

WattsBase = *Connected load of baseline lamp*

= *Actual if retrofit, if LED lumens is known – find the equivalent baseline wattage from the table below*[122]*, if unknown assume 65W* [123]

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Reflector with medium screw bases w/ diameter <=2.25"	400	449	40
	450	499	45
	500	649	50
	650	1199	65
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)	640	739	40
	740	849	45
	850	1179	50
	1180	1419	65
	1420	1789	75
	1790	2049	90
	2050	2579	100
	2580	3429	120
	3430	4270	150
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26" and ≤ 2.5" (*see exceptions below)	540	629	40
	630	719	45
	720	999	50
	1000	1199	65
	1200	1519	75
	1520	1729	90
	1730	2189	100
	2190	2899	120
	2900	3850	150
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649-1179[124]	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40

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

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

[124] The upper bounds for these categories depends on the lower bound of the next higher wattage, which varies by bulb type.

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399-639[125]	30

WattsEE = Connected load of efficient lamp
= Actual. If unknown assume12W [126]
ISR = In Service Rate or percentage of units rebated that get installed.
= 1.0[127]
HOURS = Average hours of use per year

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	2.46	898[128]
Multi Family Common Areas	16.3	5,950[129]
Unknown	2.46	898

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

	$WHFe_{Cool}$
Building with cooling	1.12[130]
Building without cooling or exterior	1.0

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[125] As above.

[126] Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc. (http://site4.marketsmartinteractive.com/products.htm)

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

[128] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 14. This assumption is consistent with the CFL measures. To date there has not been sufficient data available to provide a separate LED hours assumption, and this should be reviewed in future years.

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

[130] The value is estimated at 1.12 (calculated as 1 + (0.33 / 2.8)). 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 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-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), converted to COP = EER/3.412 = 2.8COP).

Unknown	1.09[131]

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

= 1 - ((HF / ηHeat) * %ElecHeat)

If unknown assume 0.894[132]

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

= *47%*[133] *for interior or unknown location*

= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*

= *actual. If not available use*[134]*:*

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	1.67[135]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%

---

[131] The value is estimated at 1.09 (calculated as 1 + (0.78*(0.33 / 2.8)). Based on assumption that 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[132] Calculated using defaults; 1+ ((0.47/1.67) * 0.375) = 0.894

[133] 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.

[134] 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.

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

Unknown	37.5%[136]

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

$$\Delta kWh = ((65 - 12) / 1{,}000) * 1.0 * 898 * (0.894 + (1.09 - 1))$$

$$= 46.8 \text{ kWh}$$

Multi Family Common Areas

$$\Delta kWh = ((65 - 12) / 1{,}000) * 1.0 * 5950 * (0.894 + (1.09 - 1))$$

$$= 310.3 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

	WHFd
Building with cooling	*1.24*[137]
Building without cooling or exterior	1.0
Unknown	*1.18*[138]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082[139]
	PJM CF	0.084[140]

---

[136] Based on KEMA baseline study for Maryland.

[137] The value is estimated at 1.24 (calculated as 1 + (0.66 / 2.8)). 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).

[138] The value is estimated at 1.18 (calculated as 1 + (0.78 * 0.66 / 2.8)).

[139] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 16.

[140] Ibid.

Multi Family Common Areas	PJM CF	0.43[141]
Exterior	PJM CF	0.018[142]
Unknown	Utility Peak CF	0.082
	PJM CF	0.084

Illustrative example – do not use as default assumption

$$\Delta kW_{PJM} = ((65 – 12) / 1{,}000) * 1.0 * 1.18 * 0.084$$

$$= 0.0053 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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

$$\Delta MMBtuPenalty^{143} = - ((((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.003412) / \eta Heat) * \%FossilHeat$$

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[144] *for interior or unknown location*
= *0% for exterior or unheated location*
0.003412 =*Converts kWh to MMBtu*
ηHeat = *Efficiency of heating system*
=*72%*[145]
%FossilHeat = *Percentage of home with non-electric heat*

Heating fuel	%FossilHeat
Electric	0%

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[141] 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’.

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

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

[144] 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.

[145] 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).

Fossil Fuel	100%
Unknown	62.5%[146]

Illustrative example – do not use as default assumption

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

ΔMMBtuPenalty = - (((65 – 12)/1000) * 1.0 * 898 * 0.47 * 0.003412/0.75) * 1.0

= - 0.10 MMBtu

If home heating fuel is unknown:

ΔMMBtuPenalty = - (((65 - 12)/1000) * 1.0 * 898 * 0.47 * 0.003412/0.72) * 0.625

= - 0.066 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 incremental cost for this measure is assumed to be $36[147].

Measure Life

The measure life is assumed to be 20 yrs for Residential and Multi Family in-unit, and 4.2 years for Multi Family common areas[148].

Operation and Maintenance Impacts

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[146] Based on KEMA baseline study for Maryland.

[147] Based on VEIC product review, April 2015. Baseline bulbs available in $3-$5 range, and SSL bulbs available in $20-$60 range. Incremental cost of $36 therefore assumed ($4 for the baseline bulb and $40 for the SSL). Note, this product is likely to fall rapidly in cost, so this should be reviewed frequently.

[148] The ENERGY STAR Spec for SSL Recessed Downlights requires luminaires to maintain >=70% initial light output for 25,000 hrs in a residential application. Measure life is capped at 20 years for Residentialand multi family in-unit, and calculated as 4.2 years (25000/5950) for multi family common area; http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/SSL_FinalCriteria.pdf

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

	BR-type Incandescent
Replacement Cost	$4.00
Component Life[149] (years) Residential interior and in-unit Multi Family or unknown.	2.2[150]
Multi Family Common Areas	0.34[151]

The calculated net present value of the baseline replacement costs is $19.99 for Residential interior and in-unit Multi Family and $151.72 for Multi Family common areas.

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

[150] Assumes rated life of BR incandescent bulb of 2000 hours, based on product review. Lamp life is therefore 2000/898 = 2.2 years.

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

ENERGY STAR Integrated Screw Based SSL (LED) Lamp*

Unique Measure Code: RS_LT_TOS_SSLDWN_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp (specification effective September 30, 2014) in place of an incandescent lamp. The ENERGY STAR specification can be viewed here: http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

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

Definition of Baseline Condition

The baseline wattage is assumed to be an incandescent or EISA compliant (where appropriate) bulb installed in a screw-base socket[152].

Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp.

Annual Energy Savings Algorithm

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

Where:

WattsBase = *If actual LED lumens is known – find the equivalent baseline wattage from the table below;*
If unknown assume 14.5W[153]

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

[153] Average wattage of replacement incandescent bulb was 61.2W. LED wattage from delta watts table RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals	250	449	25
	450	799	29
	800	1099	43
	1100	1599	53
	1600	1999	72
	2000	2549	125
	2550	3000	150
	3001	3999	200
	4000	6000	300
3-Way	250	449	25
	450	799	40
	800	1099	60
	1100	1599	75
	1600	1999	100
	2000	2549	125
	2550	2999	150
Globe (medium and intermediate bases less than 750 lumens)	90	179	10
	180	249	15
	250	349	25
	350	749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10
	90	149	15
	150	299	25
	300	749	40
Globe (candelabra bases less than 1050 lumens)	90	179	10
	180	249	15
	250	349	25
	350	499	40
	500	1049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10
	90	149	15
	150	299	25
	300	499	40
	500	1049	60
Reflector with medium screw bases w/ diameter <=2.25"	400	449	40
	450	499	45
	500	649	50

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	650	1199	65
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)	640	739	40
	740	849	45
	850	1179	50
	1180	1419	65
	1420	1789	75
	1790	2049	90
	2050	2579	100
	2580	3429	120
	3430	4270	150
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26'' and ≤ 2.5" (*see exceptions below)	540	629	40
	630	719	45
	720	999	50
	1000	1199	65
	1200	1519	75
	1520	1729	90
	1730	2189	100
	2190	2899	120
	2900	3850	150
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649-1179[154]	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399-639[155]	30

ISR = *In Service Rate or percentage of units rebated that get installed.*
= *0.95*[156]

HOURS = *Average hours of use per year*

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[154] The upper bounds for these categories depends on the lower bound of the next higher wattage, which varies by bulb type.

[155] As above.

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

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	2.46	898[157]
Multi Family Common Areas	16.3	5,950[158]
Exterior	4.5	1,643[159]
Unknown	3.0	1,100[160]

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

	$WHFe_{Cool}$
Building with cooling	1.12[161]
Building without cooling or exterior	1.0
Unknown	1.09[162]

$WHFe_{Heat}$ = *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).*

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[157] Based on Navigant Consulting "EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study." April 10, 2015, page 14. To date there has not been sufficient data available to provide a separate LED hours assumption, and this should be reviewed in future years.

[158] 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.

[159] 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

[160] Based on EmPOWER Maryland 2011Evaluation Report; Chapter 5: Residential Lighting and Appliances.

[161] The value is estimated at 1.12 (calculated as 1 + (0.33 / 2.8)). 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 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-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), converted to COP = EER/3.412 = 2.8COP).

[162] The value is estimated at 1.09 (calculated as 1 + (0.78*(0.33 / 2.8)). Based on assumption that 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

$= 1 - ((HF / \eta Heat) * \%ElecHeat)$

If unknown assume 0.894[163]

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[164] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[165]*:*

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	1.67[166]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[167]

Illustrative example – do not use as default assumption

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[163] Calculated using defaults; 1+ ((0.47/1.67) * 0.375) = 0.894

[164] 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.

[165] 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.

[166] 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.

[167] Based on KEMA baseline study for Maryland.

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" is installed in a residential interior location in 2014.

$$\Delta kWh = ((50 - 10)/ 1{,}000) * 0.95 * 898 * (0.894 + (1.09 - 1))$$

$$= 33.6 \text{ kWh}$$

Baseline Adjustment

Currently the EISA legislation only applies to omnidirectional bulbs, with Decorative and Directional being exceptions. If additional legislation is passed, this TRM will be adjusted accordingly.

To account for these new standards, the savings for this measure should be reduced to account for the higher baselines in 2012 - 2014 and 2020. The following table shows the calculated adjustments for each measure type[168]:

Lower Lumen Range	Upper Lumen Range	Mid life Adjustment in 2020
200	449	100%
450	799	5%
800	1099	11%
1,100	1599	13%
1,600	1999	15%
2,000	2549	100%
2,550	3000	100%
3001	3999	100%
4000	6000	100%

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

	WHFd
Building with cooling	*1.24*[169]

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[168] See ‘ESTAR Integrated Screw SSL Lamp_032014.xls’ for details.

[169] The value is estimated at 1.24 (calculated as 1 + (0.66 / 2.8)). 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

Building without cooling or exterior	1.0
Unknown	*1.18*[170]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082[171]
	PJM CF	0.084[172]
Multi Family Common Areas	PJM CF	0.43[173]
Exterior	PJM CF	0.018[174]
Unknown	Utility Peak CF	0.082
	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 in 2014.

$$\Delta kW_{PJM} = ((50 - 10)/ 1{,}000) * 0.95 * 1.18 * 0.084$$

$$= 0.0038 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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

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

Where:

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the PJM coincident definition).

[170] The value is estimated at 1.18 (calculated as 1 + (0.78 * 0.66 / 2.8)).

[171] Based on Navigant Consulting “EmPOWER Maryland Evaluation Year 5 (June 1, 2013 – May 31, 2014) Residential Lighting Program: Hours of Use/Metering Study.” April 10, 2015, page 16.

[172] Ibid.

[173] 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’.

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

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[175] *for interior or unknown location*
= *0% for exterior or unheated location*

0.003412 =*Converts kWh to MMBtu*

ηHeat = *Efficiency of heating system*
=*72%*[176]

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

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[177]

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 in 2014.

$$\Delta \text{MMBtuPenalty} = -\ ((50 - 10)/\ 1{,}000) * 0.95 * 898 * 0.47 * 0.003412/0.72) * 0.625$$

$$= -\ 0.048 \text{ MMBtu}$$

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 incremental cost for this measure is presented below[178]:

	Lamp Costs		Incremental Cost
	Efficient	Baseline	

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[175] 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.

[176] 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).

[177] Based on KEMA baseline study for Maryland.

[178] All costs based on VEIC study of units rebated through the Efficiency Vermont Retail program and retail pricing from online, February 2015.

	LED Wattage	LED	Incandescent	EISA 2012-2014 Compliant	Incandescent	EISA 2012-2014 Compliant
Omnidirectional	<15W	$12.41	n/a	$1.50	n/a	$10.91
	>=15W	$24.26	n/a	$1.50	n/a	$22.76
Decorative	<15W	$12.76	$1.00	n/a	$11.76	n/a
	15<= to <25W	$25.00	$1.00	n/a	$24.00	n/a
	>=25W	$25.00	$1.00	n/a	$24.00	n/a
Directional	< 20W	$22.42	$5.00	n/a	$17.43	n/a
	>=20W	$70.78	$5.00	n/a	$65.78	n/a

Measure Life

The measure life is assumed to be:

	Rated Life[179]	Measure Life		
		Residential interior, in-unit Multi Family or unknown	Multi Family Common Areas	Exterior
Omnidirectional	25,000	20	4.2	15.2
Decorative	15,000	16.7	2.5	9.1
Directional	25,000	20	4.2	15.2

Operation and Maintenance Impacts

For Decorative and Directional bulbs, without a baseline shift, the following component costs and lifetimes will be used to calculate O&M savings:

Lamp Type	Baseline Lamp Cost	Lamp Lifetime[180]		
		Residential interior, in-unit Multi Family and unknown	Multi Family Common Areas	Exterior

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[179] The ENERGY STAR Spec for Integrated Screw Based SSL bulbs requires lamps to maintain >=70% initial light output for 25,000 hrs in a residential application for omnidirectional and directional bulbs, and 15,000 hrs for decorative bulbs. Lifetime capped at 20 years.

[180] Assumes incandescent baseline lamp life of 1000 hours.

Decorative	$3.40	1.1	0.2	0.6
Directional <15W	$6.16	1.1	0.2	0.6
Directional >=15W	$6.47	1.1	0.2	0.6

For Omni-directional bulbs, to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the LED is calculated (see 'ESTAR Integrated Screw SSL Lamp_032015.xls'). The key assumptions used in this calculation are documented below:

	EISA 2012-2014 Compliant	EISA 2020 Compliant
Replacement Cost <10W	$1.23	$2.86
Replacement Cost >=10W	$1.41	$3.19
Component Life (hours)	1000	8,000 (for Residential Interior and Exterior) 10,000 (for MF Common Areas)[181]

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

			NPV of baseline Replacement Costs		
	Location	LED Wattage	2015	2016	2017
Omnidirectional	Residential interior, in-unit Multi Family and unknown	<10W	$5.30	$4.82	$4.31
		>=10W	$5.68	$5.20	$4.69
	Multi Family Common Areas	<10W	$21.50	$20.80	$17.14
		>=10W	$21.50	$20.80	$17.14
	Exterior	<10W	$9.77	$8.88	$7.96
		>=10W	$9.77	$8.88	$7.96

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[181] Assumed higher lamp life for instances with longer run hours and therefore less switching.

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*Total Volume):[182]

Product Category	Volume (cubic feet)	Assumptions up to September 2014		Assumptions after September 2014	
		Federal Baseline Maximum Energy Usage in kWh/year[183]	ENERGY STAR Maximum Energy Usage in kWh/year[184]	Federal Baseline Maximum Energy Usage in kWh/year[185]	ENERGY STAR Maximum Energy Usage in kWh/year[186]
Upright Freezers with Manual Defrost	7.75 or greater	7.55*AV+258.3	6.795*AV+232.47	5.57*AV + 193.7	5.01*AV + 174.3
Upright Freezers with Automatic Defrost	7.75 or greater	12.43*AV+326.1	11.187*AV+293.49	8.62*AV + 228.3	7.76*AV + 205.5
Chest Freezers and all other Freezers except Compact Freezers	7.75 or greater	9.88*AV+143.7	8.892*AV+129.33	7.29*AV + 107.8	6.56*AV + 97.0
Compact Upright Freezers with Manual Defrost	< 7.75 and <=36 inches in height	9.78*AV+250.8	7.824*AV+200.64	8.65*AV + 225.7	7.79*AV + 203.1
Compact Upright Freezers with Automatic Defrost	< 7.75 and <=36 inches in height	11.40*AV+391	9.12*AV+312.8	10.17*AV + 351.9	9.15*AV + 316.7
Compact Chest Freezers	<7.75 and <=36 inches in height	10.45*AV+152	8.36*AV+121.6	9.25*AV + 136.8	8.33*AV + 123.1

Definition of Baseline Condition

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

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

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

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

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

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. Note that the Federal Standard will increase on September 1, 2014.

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 20% more energy efficient than the minimum federal government standard (NAECA).

Note that the ENERGY STAR level will increase in line with the Federal Standard increase on September 1, 2014.

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 Freezers with Manual Defrost before September 2014:

$$\Delta kWh = (7.55 * (12 * 1.73) + 258.3) – (6.795 * (12 * 1.73) + 232.47)$$

$$= 359.5 – 323.6$$

$$= 41.5 \text{ kWh}$$

If volume is unknown, use the following default values:

Product Category	Volume Used[187]	Assumptions up to September 2014			Assumptions after September 2014			Weighting for unknown configuration
		kWh_{BASE}	kWh_{ESTAR}	kWh Savings	kWh_{BASE}	kWh_{ESTAR}	kWh Savings	
Upright Freezers with Manual Defrost	27.9	469.1	422.2	46.9	349.2	314.2	35.0	0.0%
Upright Freezers with Automatic Defrost	27.9	673.2	605.9	67.3	469.0	422.2	46.8	39.5%
Chest Freezers and all other Freezers except Compact Freezers	27.9	419.6	377.6	42.0	311.4	280.2	31.2	40.5%
Compact Upright Freezers with Manual Defrost	10.4	352.3	281.9	70.5	467.2	420.6	46.6	10.0%
Compact Upright Freezers with Automatic Defrost	10.4	509.3	407.5	101.9	635.9	572.2	63.7	6.0%
Compact Chest Freezers	10.4	260.5	208.4	52.1	395.1	355.7	39.4	4.0%

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[187] Volume is based on ENERGY STAR Calculator assumption of 16.14 ft^3 average volume, converted to Adjusted volume by multiplying by 1.73.

If configuration is unknown assume 58.8 kWh[188] for installations before September 1, 2014 and 41.2kWh for installations after September 1, 2014.

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23 [189]
LSAF = Load Shape Adjustment Factor
= 1.15 [190]

Illustrative example – do not use as default assumption
A 12 cubic foot Upright Freezers with Manual Defrost installed before September 1, 2014:

$$\Delta kW = 41.5 / 8760 * 1.23 * 1.15$$

$$= 0.0067 \text{ kW}$$

If volume is unknown, use the following default values:

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[188] 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.

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

[190] 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).

Product Category	Assumptions up to September 2014	Assumptions after September 2014
	kW Savings	kW Savings
Upright Freezers with Manual Defrost	0.0076	0.0057
Upright Freezers with Automatic Defrost	0.0109	0.0076
Chest Freezers and all other Freezers except Compact Freezers	0.0068	0.0050
Compact Upright Freezers with Manual Defrost	0.0114	0.0075
Compact Upright Freezers with Automatic Defrost	0.0164	0.0103
Compact Chest Freezers	0.0084	0.0064

If configuration is unknown assume 0.0095 kW for installations before September 1, 2014 and 0.0067kW for installations after September 1, 2014.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is $35[191].

Measure Life

The measure life is assumed to be 12 years[192].

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[191] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative. “2009 ENERGY STAR Appliances Practices Report”, submitted by Lockheed Martin, December 2009.

[192] Energy Star Freezer Calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?a8fb-c882&a8fb-c882

Operation and Maintenance Impacts

n/a

Refrigerator

Unique Measure Code(s): RS_RF_TOS_REFRIG_V0414
Effective Date: June 2014
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 specifications (defined as requiring >= 20% or >= 25% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The algorithms for calculating Federal Baseline and ENERGY STAR consumption are provided below (note, Adjusted Volume is calculated as the fresh volume + (1.63 * Freezer Volume).This is a time of sale measure characterization.

Product Category	Assumptions up to September 2014		Assumptions after September 2014	
	Federal Baseline Maximum Energy Usage in kWh/year[193]	ENERGY STAR Maximum Energy Usage in kWh/year[194]	Federal Baseline Maximum Energy Usage in kWh/year[195]	ENERGY STAR Maximum Energy Usage in kWh/year[196]
1. Refrigerators and Refrigerator-freezers with manual defrost	8.82*AV+248.4	7.056*AV+198.72	6.79AV + 193.6	6.11 * AV + 174.2
2. Refrigerator-Freezer--partial automatic defrost	8.82*AV+248.4	7.056*AV+198.72	7.99AV + 225.0	7.19 * AV + 202.5
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	9.80*AV+276	7.84*AV+220.8	8.07AV + 233.7	7.26 * AV + 210.3
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	4.91*AV+507.5	3.928*AV+406	8.51AV + 297.8	7.66 * AV + 268.0
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer	4.60*AV+459	3.68*AV+367.2	8.85AV + 317.0	7.97 * AV + 285.3

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[193] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[194] http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746
[195] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
[196] http://www.energystar.gov/products/specs/sites/products/files/ENERGY%20STAR%20Final%20Version%205.0%20Residential%20Refrigerators%20and%20Freezers%20Specification.pdf

without through-the-door ice service				
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	10.20*AV+356	8.16*AV+284.8	8.40AV + 385.4	7.56 * AV + 355.3
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	10.10*AV+406	8.08*AV+324.8	8.54AV + 432.8	7.69 * AV + 397.9

Note CEE Tier 2 standard criteria is 25% less consumption than a new baseline unit. It is assumed that after September 2014 when the Federal Standard and ENERGY STAR specifications change, the CEE Tier 2 will remain set at 25% less that the new baseline assumption.

Definition of Baseline Condition

The baseline condition is a new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency as presented above. Note that the Federal Standard will increase on September 1, 2014.

Definition of Efficient Condition

The efficient condition is a new refrigerator meeting either the ENERGY STAR or CEE TIER 2 efficiency standards as presented above. Note that the Federal Standard will increase on September 1, 2014.

Annual Energy Savings Algorithm

$$\Delta kWh = kWhBASE - kWhES$$

Where:

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

kWhEE = *Annual energy consumption of energy efficient unit as calculated in algorithm provided in table above.*

Illustrative example – do not use as default assumption

A 14 cubic foot Refrigerator and 6 cubic foot Freezer, with automatic defrost with side-mounted freezer without through-the-door ice service, installed before September 2014:

$$\Delta kWh = ((4.91 * (14 + (6 * 1.63))) + 507.5) - ((3.928 * (14 + (6 * 1.63))) + 406)$$

$$= 624.3 - 499.4$$

= 124.9 kWh

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8[197]:

Product Category	Assumptions prior to September 1st, 2014					Assumptions after September 1st, 2014					Weighting (%)
	New Baseline UEC$_{BASE}$	New Efficient UEC$_{EE}$		ΔkWh		New Baseline UEC$_{BASE}$	New Efficient UEC$_{EE}$		ΔkWh		
		ENERGY STAR	CEE T2	ENERGY STAR	CEE T2		ENERGY STAR	CEE T2	ENERGY STAR	CEE T2	
1. Refrigerators and Refrigerator-freezers with manual defrost	475.7	380.5	356.8	95.1	118.9	368.6	331.6	276.4	36.9	92.1	0.27
2. Refrigerator-Freezer--partial automatic defrost	475.7	380.5	356.8	95.1	118.9	430.9	387.8	323.2	43.1	107.7	0.27
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	528.5	422.8	396.4	105.7	132.1	441.7	397.4	331.2	44.3	110.4	57.45
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	634.0	507.2	475.5	126.8	158.5	517.1	465.4	387.8	51.7	129.3	1.40

---

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

5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	577.5	462.0	433.2	115.5	144.4	545.1	490.7	408.8	54.4	136.3	16.45
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service	618.8	495.1	464.1	123.8	154.7	601.9	550.1	451.4	51.7	150.5	0.27
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	666.3	533.0	499.7	133.3	166.6	652.9	596.1	489.6	56.8	163.2	24.10

If configuration is unknown assume 114.5 kWh[198] for ENERGY STAR and 143.1 kWh for CEE T2 for installations before September 1, 2014 and 49.1 kWh for ENERGY STAR and 127.9 kWh for CEE T2 for installations after September 1, 2014.

Summary Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23 [199]

LSAF = Load Shape Adjustment Factor

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[198] 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.

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

= 1.15 [200]

If volume is unknown, use the following defaults:

Product Category	Assumptions prior to September 2014 standard change ΔkW		Assumptions after September 2014 standard change ΔkW	
	ENERGY STAR	CEE T2	ENERGY STAR	CEE T2
1. Refrigerators and Refrigerator-freezers with manual defrost	0.014	0.018	0.006	0.014
2. Refrigerator-Freezer--partial automatic defrost	0.014	0.018	0.007	0.016
3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost	0.016	0.020	0.007	0.017
4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service	0.019	0.024	0.008	0.019
5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	0.017	0.022	0.008	0.021
6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with	0.019	0.023	0.008	0.023

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[200] 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).

through-the-door ice service				
7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service	0.020	0.025	0.009	0.025

If configuration is unknown assume 0.017 kW for ENERGY STAR and 0.022 kW for CEE T2 for installations before September 1, 2014 and 0.007 kW for ENERGY STAR and 0.019 kW for CEE T2 for installations after September 1, 2014.

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 $26 for an ENERGY STAR unit[201] and $140 for a CEE Tier 2 unit.[202]

Measure Life

The measure life is assumed to be 12 Years.[203]

Operation and Maintenance Impacts

n/a

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[201] Based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. See “Refrigerator Default Calcs.xlsx”.

[202] Based on Department of Energy, “TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers”, October 2005.

[203] From ENERGY STAR calculator: https://www.energystar.gov/index.cfm?fuseaction=refrig.calculator

Refrigerator Early Replacement

Unique Measure Code(s): RS_RF_RTR_REFRIG_0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the early removal of an existing inefficient Refrigerator unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR or CEE Tier 2 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.

This is a retrofit measure.

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, or CEE TIER 2 efficiency standards (defined as 20% or 25% above federal standards respectively).

Annual Energy Savings Algorithm

Remaining life of existing unit (first 4 years[204])

$$\Delta kWh = kWhEXIST - kWhEE$$

Remaining measure life (next 8 years)

$$\Delta kWh = kWhBASE - kWhEE$$

---

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

Where:

kWhEXIST = *Annual energy consumption of existing unit*
= *1146* [205]
kWhBASE = *Annual energy consumption of new baseline unit*
= *572.3 for units prior to September 2014*
= *511.7 for units after September 2014*[206]
kWhEE = *Annual energy consumption of ENERGY STAR unit*
= *457.8 for units prior to September 2014*
= *462.6 for units after September 2014*[207]
Or = *Annual energy consumption of CEE Tier 2 unit*
= *429.2 for units prior to September 2014*
= *383.8 for units after September 2014*[208]

Timing	Efficient unit specification	First 4 years ΔkWh	Remaining 8 years ΔkWh	Equivalent Mid Life Savings Adjustment (after 4 years)	Equivalent Weighted Average Annual Savings[209]
Assumptions prior to September 2014	ENERGY STAR	688.2	114.5	16.6%	344.0
	CEE T2	716.8	143.1	20.0%	372.6
Assumptions after September 2014	ENERGY STAR	683.4	49.1	7.2%	302.9
	CEE T2	762.2	127.9	16.8%	381.7

Summer Coincident Peak kW Savings Algorithm

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

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

[206] 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.

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

[208] kWh assumptions based on 25% less than baseline consumption and calculating a weighted average of the different configurations.

[209] These values are provided in case the utility screening tool does not allow for this mid life baseline adjustment. The values are determined by calculating the Net Present Value of the 12 year annual savings values and finding the equivalent annual savings that produces the same result. The Real Discount Rate of 5.0% is used.

Where:

TAF = Temperature Adjustment Factor
= 1.23 [210]

LSAF = Load Shape Adjustment Factor
= 1.15 [211]

Timing	Efficient unit specification	First 4 years ΔkW	Remaining 8 years ΔkW	Equivalent Mid Life Savings Adjustment (after 4 years)	Equivalent Weighted Average Annual Savings
Assumptions prior to September 2014	ENERGY STAR	0.111	0.018	16.6%	0.056
	CEE T2	0.116	0.023	20.0%	0.060
Assumptions after September 2014	ENERGY STAR	0.110	0.008	7.2%	0.049
	CEE T2	0.123	0.021	16.8%	0.062

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The initial full measure cost for an Energy Star refrigerator is assumed to be $748 and Tier 2 is $862. The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $722.[212]

Measure Life

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[210] 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.

[211] 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).

[212] Full ENERGY STAR and baseline costs based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "Refrigerator Default Calcs.xlsx". Full CEE Tier 2 cost is based upon incremental cost estimate derived from "TECHNICAL REPORT: Analysis of Amended Energy Conservation Standards for Residential Refrigerator-Freezers". http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf

The measure life is assumed to be 12 Years. [213]

Operation and Maintenance Impacts

n/a

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[213] From ENERGY STAR calculator: https://www.energystar.gov/index.cfm?fuseaction=refrig.calculator

Refrigerator and Freezer Early Retirement

Unique Measure Code(s): RS_RF_ERT_REFRIG_0414, RS_RF_ERT_FREEZE_0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure involves the removal of an existing inefficient refrigerator[214] from service, prior to its natural end of life (early retirement). The program should target refrigerators with an age greater than 10 years, though it is expected that the average age will be greater than 20 years based on other similar program performance. Savings are calculated for the estimated energy consumption during the remaining life of the existing unit[215].

Definition of Baseline Condition

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

Refrigerators:

Energy savings for retired refrigerators are based upon a linear regression model using the following coefficients[216]:

Independent Variable Description	Estimate Coefficient
Intercept	0.582
Age (years)	0.027
Pre-1990 (=1 if manufactured pre-1990)	1.055
Size (cubic feet)	0.067
Dummy: Single Door (=1 if single door)	-1.977

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[214] 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.

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

[216] Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Recycling Program." March 21, 2014, page 32.

Dummy: Side-by-Side (= 1 if side-by-side)	1.071
Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit)	0.605
Interaction: Located in Unconditioned Space x HDD/365.25	-0.045
Interaction: Located in Unconditioned Space x CDD/365.25	0.020

ΔkWh = [0.582 + (Age * 0.027) + (Pre-1990 * 1.055) + (Size * 0.067) + (Single-Door * -1.977) + (Side-by-side * 1.071) + (Primary * 0.605) + (HDD/365.25 * Unconditioned * -0.045) + (CDD/365.25 * Unconditioned * 0.020)] * 365.25 * Part Use Factor

Where:

HDD = *Heating Degree Days*
= *dependent on location. Use actual for location or defaults below*[217]

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

CDD = *Cooling Degree Days*
= *dependent on location. Use actual for location or defaults below*[218]

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

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[217] 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.

[218] Ibid.

Part Use Factor *= To account for those units that are not running throughout the entire year as reported by the customer. Default of 0.89*[219]

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

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

ΔkWh = [0.582 + (15.36 * 0.027) + (0.14 * 1.055) + (19.36 * 0.067) + (0.3 * -1.977) + (0.03 * 1.071) + (0.7 * 0.605) + (1.25 * -0.045) + (4.72 * 0.020)] * 365.25 * 0.89

= 761 kWh

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients[220]:

Independent Variable Description	Estimate Coefficient
Intercept	-0.892
Age (years)	0.038
Pre-1990 (=1 if manufactured pre-1990)	0.695
Size (cubic feet)	0.129
Chest Freezer Configuration (=1 if chest freezer)	0.35
Interaction: Located in Unconditioned Space x HDD/365.25	0.070
Interaction: Located in Unconditioned Space x CDD/365.25	-0.031

ΔkWh = [-0.892 + (Age * 0.038) + (Pre-1990 * 0.695) + (Size * 0.129) + (Chest Freezer * 0.35) + (HDDs/365.25 * Unconditioned * 0.070) +

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[219] Based on EmPower DRAFT 2010 Interim Evaluation Report Chapter 5: Lighting and Appliances.

[220] Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Recycling Program." March 21, 2014, page 33.

(CDDs/365.25 * Unconditioned * -0.031)] * 365.25 * Part Use Factor

Illustrative example – can be used as default assumption only if required data tracking is not available
Using participant population mean values from BGE EY4 and default part use factor:

ΔkWh = [-0.892 + (19.59 * 0.038) + (0.29 * 0.695) + (14.34 * 0.129) + (0.24 * 0.35) + (0.46 * 0.070) + (1.76 * -0.031)] * 365.25 * 0.89

= 639 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (ΔkWh/8760) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor
= 1.23 [221]
LSAF = Load Shape Adjustment Factor
= 1.066 [222]

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:

ΔkW = 761/8760 * 1.23 * 1.066

= 0.114 kW

Freezer:

ΔkW = 639/8760 * 1.23 * 1.066

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[221] 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.

[222] 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.

= 0.114 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure will be the actual cost associated with the removal and recyling of the secondary refrigerator.

Measure Life

The measure life is assumed to be 8 Years.[223]

Operation and Maintenance Impacts

n/a

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[223] KEMA "Residential refrigerator recycling ninth year retention study", 2004.

Central Furnace Efficient Fan Motor

Unique Measure Code(s): RS_HV_RTR_FANMTR_0510 and 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 [224]

Cooling Season kWh Savings from efficient fan motor = 178kWh [225]

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[224] 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).

[225] 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

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0$ [226]

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 $200.[227]

Measure Life

The measure life is assumed to be 18 years.[227]

Operation and Maintenance Impacts

n/a

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to Southern Wisconsin (1050/487). Full load hour estimates from: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls.

[226] 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.

[227] Sachs and Smith, April 2003; Saving Energy with Efficient Furnace Air Handlers: A Status Update and Program Recommendations.

Window A/C

Unique Measure Code(s): RS_HV_TOS_RA/CES_0414 and 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 either the ENERGY STAR or CEE TIER 2 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)	CEE TIER 2 (EER)
Without Reverse Cycle	< 8,000	11.0	10.0	11.2	10.4	11.6
	8,000 to 10,999	10.9	9.6	11.3	9.8	11.8
	11,000 to 13,999	10.9	9.5	11.3	9.8	11.8
	14,000 to 19,999	10.7	9.3	11.2	9.8	11.6
	20,000 to 24,999	9.4	9.4	9.8	9.8	10.2
	>=25,000	9.0	9.4	9.8	9.8	10.2
With Reverse Cycle	<14,000	9.8	9.3	10.4	9.8	11.8
	14,000 to 19,999	9.8	8.7	10.4	9.2	11.6
	>=20,000	9.3	8.7	9.8	9.2	10.2
Casement only		9.5		10.0		
Casement-Slider		10.4		10.9		

Definition of Baseline Condition

The baseline condition is a window AC unit that meets the minimum federal efficiency standards as of June 1, 2014[228] presented above.

Definition of Efficient Condition

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[228] Although the Federal baseline presented does not come in to effect until June 2014, (http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41) according to ENERGY STAR Shipment Data the estimated market penetration of ENERGY STAR v2.0 Room AC went from 33% in 2010 to 62% in 2011 and 58% in 2012. The new Federal Standard level is equivalent to ENERGY STAR v2.0 and with the market preparing for the Standard change it is appropriate to use the updated rating from the start of the year.

The baseline condition is a window AC unit that meets either the ENERGY STAR v3.0 as of October 1, 2013 or CEE TIER 2 efficiency standards presented above.

Annual Energy Savings Algorithm

$$\Delta kWH = (Hours * BTU/hour * (1/EERbase - 1/EERee))/1000$$

Where:

Hours = *Run hours of Window AC unit*
= *325* [229]

BTU/hour = *Size of rebated unit*
When available, the actual size of the rebated unit should be used in the calculation. In the absence of this data, the following default value can be used:
= *8500* [230]

EERbase = *Efficiency of baseline unit in Btus per Watt-hour*
= *Actual (see table above)*
If average deemed value required use 10.9 [231]

EERee = *Efficiency of ENERGY STAR unit in Btus per Watt-hour*
= *Actual*
If average deemed value required use 11.3 [232] *for an ENERGY STAR unit or 11.8 for CEE Tier 2* [233]

Using deemed values above:

$\Delta kWH_{ENERGY\ STAR}$
= (325 * 8500 * (1/10.9 – 1/11.3)) / 1000
= 9.0 kWh

$\Delta kWH_{CEE\ TIER\ 2}$
= (325 * 8500 * (1/10.9 – 1/11.8)) / 1000
= 19.3 kWh

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[229] 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.

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

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

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

[233] Minimum qualifying for CEE Tier 2 most common Room AC type – 8000-14,999 capacity range with louvered sides.

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = BTU/hour * (1/EERbase - 1/EERee))/1000 * CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [234]

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*[235]

Using deemed values above:

$\Delta kW_{ENERGY\ STAR\ SSP}$
= (8500 * (1/10.9 – 1/11.3)) / 1000 * 0.31
= 0.009 kW

$\Delta kW_{CEE\ TIER\ 1\ SSP}$
= (8500 * (1/10.9 – 1/11.8)) / 1000 * 0.31
= 0.018 kW

$\Delta kW_{ENERGY\ STAR\ PJM}$
= (8500 * (1/10.9 – 1/11.3)) / 1000 * 0.30
= 0.008 kW

$\Delta kW_{CEE\ TIER\ 1\ PJM}$
= (8500 * (1/10.9 – 1/11.8)) / 1000 * 0.30
= 0.018 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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

[235] Consistent with coincidence factors found in:
RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf).

Incremental Cost

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE TIER 2 unit.[236]

Measure Life

The measure life is assumed to be 12 years.[237]

Operation and Maintenance Impacts

n/a

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[236] Based on field study conducted by Efficiency Vermont.

[237] 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

ENERGY STAR Central A/C*

Unique Measure Code(s): RS_HV_TOS_CENA/C_0415, RS_HV_RTR_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	13	11
ENERGY STAR	14.5	12

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.

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.

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.

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:

$$\Delta kWH = (Hours * BTU/hour * (1/SEERbase - 1/SEERee))/1000$$

Early replacement[238]:

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

$$= ((Hours * BTU/hour * (1/SEERexist - 1/SEERee))/1000)$$

ΔkWH for remaining measure life (next 12 years):

$$= ((Hours * BTU/hour * (1/SEERbase - 1/SEERee))/1000)$$

Where:

Hours = *Full load cooling hours*

Dependent on location as below:

Location	*Run Hours*
Wilmington, DE	*524* [239]
Baltimore, MD	*542* [240]
Washington, DC	*681*

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

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[238] 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).

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

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

SEERbase *= Seasonal Energy Efficiency Ratio Efficiency of baseline unit*
= 13 [241]
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 10.0 .

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 14.5, in Baltimore:

ΔkWH = (542 * 36000 * (1/13 – 1/14.5)) / 1000

= 155 kWh

Early Replacement example: a 3 ton unit with SEER rating of 14.5 replaces an existing unit in Baltimore:

ΔkWH (for first 6 years) = (542 * 36000 * (1/10 – 1/14.5)) / 1000

= 606 kWh

ΔkWH (for next 12 years) = (542 * 36000 * (1/13 – 1/14.5)) / 1000

= 155 kWh

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

ΔkW = BTU/hour * (1/EERbase - 1/EERee)/1000 * CF

Early replacement:

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[241] Minimum Federal Standard.

[242] VEIC estimate based on Department of Energy Federal Standard between 1992 and 2006. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

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

= BTU/hour * (1/EERexist - 1/EERee)/1000 * CF

ΔkW for remaining measure life (next 12 years):

= BTU/hour * (1/EERbase - 1/EERee)/1000 * CF

Where:

EERbase = *Energy Efficiency Ratio Efficiency of baseline unit*
= *11.2* [243]
EERexist = *EER Efficiency of existing unit*
= *Actual EER of unit should be used, if EER is unknown, use 9.2*[244]
EERee = *Energy Efficiency Ratio Efficiency of ENERGY STAR unit*
= *Actual installed*
CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [245]
CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [246]

Illustrative example – do not use as default assumption
Time of Sale example: a 3 ton unit with EER rating of 12:

ΔkW_{SSP} = (36000 * (1/11.2 – 1/12)) / 1000 * 0.69
= 0.15 kW

ΔkW_{PJM} = (36000 * (1/11.2 – 1/12)) / 1000 * 0.66
= 0.14 kW

Early Replacement example: a 3 ton unit with SEER rating of 14.5 replaces an existing unit in Baltimore:

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[243] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (13) and equals EER 11.2. To perform this calculation we are using this formula: (-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).

[244] Based on SEER of 10,0, using formula above to give 9.2 EER.

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

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

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

$$\Delta kW_{SSP} = (36000 * (1/9.2 - 1/12)) / 1000 * 0.69$$
$$= 0.63 \text{ kW}$$

$$\Delta kW_{PJM} = (36000 * (1/9.2 - 1/12)) / 1000 * 0.66$$
$$= 0.60 \text{ kW}$$

ΔkW for remaining measure life (next 12 years):

$$\Delta kW_{SSP} = (36000 * (1/11.2 - 1/12)) / 1000 * 0.69$$
$$= 0.15 \text{ kW}$$

$$\Delta kW_{PJM} = (36000 * (1/11.2 - 1/12)) / 1000 * 0.66$$
$$= 0.14 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

Time of Sale:

The incremental cost for this measure is provided below:[247]

Efficiency Level	Cost per Ton
SEER 14	$95
SEER 15	$181
SEER 16	$273
SEER 17	$365
SEER 18	$458
SEER 19	$550
SEER 20	$642
SEER 21	$734

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[247] Costs based upon average cost per ton from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. Note SEER 17 and 18 are extrapolated from other data points.

Early replacement:
The incremental capital cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume (note these costs are per ton of unit capacity)[248]:

Efficiency (SEER)	Full Retrofit Cost (including labor) per Ton of Capacity ($/ton)
14	$2,286
15	$2,403
16	$2,495
17	$2,588
18	$2,680
19	$2,772
20	$2,864
21	$2,956

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $2,185 per ton[249]. This cost should be discounted to present value using the utilities discount rate.

Measure Life

The measure life is assumed to be 18 years.[250]

Remaining life of existing equipment is assumed to be 6 years[251].

Operation and Maintenance Impacts

n/a

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[248] Costs based upon average cost per ton for Equipment and Labor from Itron Measure Cost Study Results Matrix Volume 1 (part of “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014).

[249] Ibid.

[250] 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

[251] Assumed to be one third of effective useful life

Duct Sealing*

Unique Measure Code: RS_HV_RTR_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 requires 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/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.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)

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"

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

Where:

DE_{after} = *Distribution Efficiency after duct sealing*

DE_{before} = *Distribution Efficiency before duct sealing*

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	*FLHcool*
Wilmington, DE	*524* [252]

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[252] 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)

Baltimore, MD	*542* [253]
Washington, DC	*681*

BTU/hour = *Size of equipment in BTU/hour (note 1 ton = 12,000BTU/hour)*
= *Actual*
ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available use*[254]*:*

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

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

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

Energy Savings:

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

$$= 191 \text{ kWh}$$

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

$$kWh = (((((DE_{after} - DE_{before})/ DE_{after})) * FLHheat * BTU/hour) / 1{,}000{,}000 / \eta Heat) * 293.1$$

Where:

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

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[253] 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.

[254] 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.

Location	FLHheat
Wilmington, DE	*935*[255]
Baltimore, MD	*866*[256]
Washington, DC	*822*

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

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[257]*:*

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

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

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

Energy Savings:

$$\Delta kWh = ((((0.90 – 0.80)/0.90) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1$$

$$= 406 \text{ kWh}$$

Methodology 2: Modified Blower Door Subtraction

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[255] 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)

[256] 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.

[257] 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.

Claiming Cooling savings from reduction in Air Conditioning Load:

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

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

Where:

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

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

SCF = *Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.*

b. Calculate duct leakage reduction, convert to $CFM25_{DL}$[258] and factor in Supply and Return Loss Factors

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

Where:

SLF = *Supply Loss Factor*
= *% leaks sealed located in Supply ducts * 1* [259]
Default = 0.5[260]

RLF = *Return Loss Factor*
= *% leaks sealed located in Return ducts * 0.5*[261]

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[258] 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).

[259] 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/sites/default/files/documents/duct_blaster_manual_series_b_-_dg700.pdf

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

[261] 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

Default = 0.25[262]

c. Calculate Energy Savings:

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

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25

Capacity = Capacity of Air Cooling system (tons)

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

FLHcool = Full Load Cooling Hours

= Dependent on location as below:

Location	*FLHcool*
Wilmington, DE	*524* [263]
Baltimore, MD	*542* [264]
Washington, DC	*681*

BTU/hour = Size of equipment in BTU/hour (note 1 ton = 12,000BTU/hour)

= Actual

ηCool = Efficiency in SEER of Air Conditioning equipment

= actual. If not available use[265]*:*

Equipment Type	*Age of Equipment*	*SEER Estimate*
Central AC	*Before 2006*	*10*
	After 2006	*13*

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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/sites/default/files/documents/duct_blaster_manual_series_b_-_dg700.pdf

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

[263] 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)

[264] 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.

[265] 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.

Heat Pump	*Before 2006*	*10*
	2006-2014	*13*
	2015 on	*14*

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

Before:

$CFM50_{\text{Whole House}}$ = 4,800 CFM50
$CFM50_{\text{Envelope Only}}$ = 4,500 CFM50
House to duct pressure = 45 Pascals
= 1.29 SCF (Energy Conservatory look up table)

After:

$CFM50_{\text{Whole House}}$ = 4,600 CFM50
$CFM50_{\text{Envelope Only}}$ = 4,500 CFM50
House to duct pressure = 43 Pascals
= 1.39 SCF (Energy Conservatory look up table)

Duct Leakage at CFM50:

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

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

Duct Leakage reduction at CFM25:

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

Energy Savings:

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

$$= 170 \text{ kWh}$$

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

ΔkWh = ((($\Delta CFM25_{DL}$ / (Capacity * 400)) * FLHheat * BTU/hour) / 1,000,000 / ηHeat) * 293.1

Where:

$\Delta CFM25_{DL}$ = Duct leakage reduction in CFM25
Capacity = Capacity of Air Cooling system (tons)
400 = Conversion of Capacity to CFM (400CFM / ton)
FLHheat = Full Load Heating Hours
= Dependent on location as below:

Location	FLHheat
Wilmington, DE	*935*[266]
Baltimore, MD	*866*[267]
Washington, DC	*822*

BTU/hour = Size of equipment in BTU/hour (note 1 ton = 12,000BTU/hour)
= Actual
ηHeat = Efficiency in COP of Heating equipment
= actual. If not available use[268]*:*

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

Illustrative example – do not use as default assumption
Duct sealing in a 3-ton 2.5 COP heat pump heated house in Baltimore, MD with the blower door results described above:

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[266] 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)

[267] 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.

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

ΔkWh = (((119 / (3 * 400)) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1

= 362 kWh

Methodology 3: Duct Blaster Testing

Claiming Cooling savings from reduction in Air Conditioning Load:

$\Delta kWh_{cooling}$ = (((Pre_CFM25 – Post_CFM25)/ (Capacity * 400)) * FLHcool * BTU/hour) / 1000 / ηCool

Where:

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

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

All other variables as provided above.

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

Pre_CFM25 = 220 CFM25
Post_CFM25 = *80 CFM25*

ΔkWh = (((220 - 80) / (3 * 400)) * 524 * 36,000) / 1,000 / 11

= 200 kWh

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

ΔkWh = (((Pre_CFM25 – Post_CFM25/ (Capacity * 400)) * FLHheat * BTU/hour) / 1,000,000 / ηHeat) * 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:

ΔkWh = ((((220 - 80) / (3 * 400)) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1

= 426 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh / FLHcool * CF

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [269]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [270]

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

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

ΔMMBTUfossil fuel = ((((DE_{after} – DE_{before})/ DE_{after})) * FLHheat * BTU/hour) / 1,000,000 / ηHeat

Where:

DE_{after} = *Distribution Efficiency after duct sealing*
DE_{before} = *Distribution Efficiency before duct sealing*
FLHheat = *Full Load Heating Hours*
= *620*[271]
BTU/hour = *Capacity of Heating System*

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[269] 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.

[270] 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.

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

= *Actual*

ηHeat = *Efficiency of Heating equipment*

= *Actual*[272]*. If not available use 84%*[273]*.*

Illustrative example – do not use as default assumption

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

DE_{before} = 0.80

DE_{after} = 0.90

Energy Savings:

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

= 8.6 MMBtu

Methodology 2: Modified Blower Door Subtraction

ΔMMBTU = ((($\Delta CFM25_{DL}$ / (BTU/hour * 0.0126)) * FLHheat * BTU/hour) / 1,000,000 / ηHeat

Where:

$\Delta CFM25_{DL}$ = *Duct leakage reduction in CFM25*

BTU/hour = *Capacity of Heating System (BTU/hour)*

= *Actual*

0.0126 = *Conversion of Capacity to CFM (0.0126CFM / BTU/hour)*[274]

FLHheat = *Full Load Heating Hours*

= *620*[275]

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

[273] 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%.

[274] 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.

[275] 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”,

ηHeat = *Efficiency of Heating equipment*
= *Actual*[276]*. If not available use 84%*[277]*.*

Illustrative example – do not use as default assumption
Duct sealing in a house with a 100,000BTU/hour, 80% AFUE natural gas furnace and with the blower door results described above:

Energy Savings:
ΔMMBTU = (((119 / (100,000 * 0.0126)) * 620 * 100,000) / 1,000,000 / 0.80

= 7.3 MMBtu

Methodology 3: Duct Blaster Testing

ΔMMBTU = (((Pre_CFM25 – Post_CFM25/ (BTU/hour * 0.0126)) * FLHheat * BTU/hour) / 1,000,000 / ηHeat

Where:

All variables as provided above

Illustrative example – do not use as default assumption
Duct sealing in a house with a 100,000BTU/hour, 80% AFUE natural gas furnace and with the duct blaster results described above:

Energy Savings:
ΔMMBTU = (((220 - 80 / (100,000 * 0.0126)) * 620 * 100,000) / 1,000,000 / 0.80

= 8.6 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual labor and material cost to seal the ducts.

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

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

[277] 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%.

Measure Life

The measure life is assumed to be 20 years[278].

Operation and Maintenance Impacts

n/a

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[278] 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

Air Source Heat Pump*

Unique Measure Code: RS_HV_TOS_ASHP_0415, RS_HV_RTR_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[279]
Federal Standard as of 1/1/2015	8.2	14	11.8[280]
ENERGY STAR	8.2	14.5	12

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.

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.

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.

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

[280] 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.

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:

$$\Delta kWH = (FLHcool * BTU/hour * (1/SEERbase - 1/SEERee))/1{,}000 + (FLHheat * BTU/hour * (1/HSPFbase - 1/HSPFee))/1{,}000$$

Early replacement[281]:

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

$$= (FLHcool * BTU/hour_{Cool} * (1/SEERexist - 1/SEERee))/1{,}000 + (FLHheat * BTU/hour_{Heat} * (1/HSPFexist - 1/HSPFee))/1{,}000$$

ΔkWH for remaining measure life (next 12 years):

$$= (FLHcool * BTU/hour_{Cool} * (1/SEERbasereplace - 1/SEERee))/1{,}000 + (FLHheat * BTU/hour_{Heat} * (1/HSPFbasereplace - 1/HSPFee))/1{,}000$$

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[281] 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).

Where:

FLHcool = *Full Load Cooling Hours*
= *Dependent on location as below:*

Location	*FLHcool*
Wilmington, DE	*719* [282]
Baltimore, MD	*744* [283]
Washington, DC	*935*

BTU/hour$_{Cool}$ = *Cooling capacity of Air Source Heat Pump (1 ton = 12,000BTU/hour)*
= *Actual*

SEERbase = *Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump*
= *14*[284]

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

Existing Cooling System	*SEERexist*[285]
Air Source Heat Pump or Central AC	*10.0*
No central cooling[286]	*Make '1/SEERexist' = 0*

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

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[282] 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)

[283] 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.

[284] Minimum Federal Standard

[285] VEIC estimate based on Department of Energy Federal Standard between 1992 and 2006. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[286] 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.

SEERbasereplace = *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

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

Location	FLHheat
Wilmington, DE	*935*[287]
Baltimore, MD	*866*[288]
Washington, DC	*822*

$BTU/hour_{Heat}$ = *Heating capacity of Air Source Heat Pump (1 ton = 12,000BTU/hour)*
= *Actual*

HSPFbase = *Heating Seasonal Performance Factor of baseline Air Source Heat Pump*
= *8.2* [289]

HSPFexist = *Heating System Performance Factor*[290] *of existing heating system (kBtu/kWh)*

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

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[287] 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)

[288] 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.

[289] Minimum Federal Standard

[290] 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.

Existing Heating System	*HSPF_exist*
Air Source Heat Pump	*5.96* [291]
Electric Resistance	*3.41* [292]

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

HSPFbasereplace = *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 14.5 and HSPF of 8.4 in Baltimore, MD:

ΔkWH = (744 * 36,000 * (1/14 - 1/14.5))/1,000 + (866 * 36,000 * (1/8.2 – 1/8.4))/1,000

= 156.5 kWh

Early Replacement example: a 3 ton unit with a SEER rating of 14.5 and HSPF of 8.4 in Baltimore, MD is installed replacing an existing working Central AC system with a SEER rating of 10 and electric resistance heating:

ΔkWH (for first 6 years) = (744 * 36,000 * (1/10 - 1/14.5))/1,000 + (866 * 36,000 * (1/3.41 – 1/8.4))/1,000

= 6,262 kWh

ΔkWH (for remaining 12 years) = (744 * 36,000 * (1/13 - 1/14.5))/1,000 + (866 * 36,000 * (1/3.41 – 1/8.4))/1,000

= 5,644 kWh

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[291] 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 10.0.

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

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$$\Delta kW = BTU/hour_{Cool} * (1/EERbase - 1/EERee))/1{,}000 * CF$$

Early replacement:

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

$$= BTU/hour_{Cool} * (1/EERexist - 1/EERee)/1000 * CF$$

ΔkW for remaining measure life (next 12 years):

$$= BTU/hour_{Cool} * (1/EERbasereplace - 1/EERee)/1000 * CF$$

Where:

EERbase = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*
= 11.8 [293]

EERexist = Energy Efficiency Ratio of existing cooling system (kBTU/hour / kW)

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

$EER = (-0.02 * SEER^2) + (1.12 * SEER)$ [294]

If SEER rating unavailable use:

Existing Cooling System	EERexist[295]
Air Source Heat Pump or Central AC	9.2
No central cooling[296]	Make '1/EERexist' = 0

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[293] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (14) and equals EER 11.8. To perform this calculation we are using this formula: (-0.02 * 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).

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

[295] Estimated by converting the SEER 10 assumption using the algorithm provided.

[296] 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.

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

EERbasereplace = *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	11.0

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [297]

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [298]

Illustrative example – do not use as default assumption
Time of Sale example: a 3 ton unit with EER rating of 12.0 in Baltimore, MD:

ΔkW_{SSP} = 36,000 * (1/11.8 - 1/12))/1,000 * 0.69

= 0.035kW

Early Replacement example: a 3 ton unit with a SEER rating of 14.5 and HSPF of 8.4 in Baltimore, MD is installed replacing an existing working Central AC system with a SEER rating of 10 and electric resistance heating:

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

ΔkW_{SSP} = 36,000 * (1/9.2 - 1/12))/1,000 * 0.69

= 0.63 kW

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[297] 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.

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

ΔkW for remaining measure life (next 12 years):

$$\Delta kW_{SSP} = 36{,}000 * (1/11 - 1/12))/1{,}000 * 0.69$$

$$= 0.15 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided in the table below[299]. Note these incremental costs are per ton of capacity, so for example a 3 ton, 15 SEER unit would have an incremental cost of $510.

Efficiency (SEER)	Incremental Cost per Ton of Capacity
15	$170
16	$340
17	$529
18	$710

Early replacement: The capital cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume the following (note these costs are per ton of unit capacity)[300]:

Efficiency (SEER)	Full Retrofit Cost (including labor) per Ton of Capacity ($/ton)
15	$2,544
16	$3,120
17	$3,309
18	$3,614

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[299] Costs based upon average cost per ton from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. Note SEER 17 and 18 are extrapolated from other data points.

[300] Costs based upon average cost per ton for Equipment and Labor from Itron Measure Cost Study Results Matrix Volume 1 (part of “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014). Note SEER 17 and 18 are extrapolated from other data points.

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $2,355 per ton of capacity[301]. This cost should be discounted to present value using the utilities discount rate.

Measure Life

The measure life is assumed to be 18 years[302].

Operation and Maintenance Impacts

n/a

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[301] Ibid.

[302] 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*

Unique Measure Code: RS_HV_TOS_MSHP_0415, RS_HV_RTR_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) (DHP).

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 heating and/or cooling load the DHP will replace.

Definition of Baseline Condition

The baseline condition for early replacement is the existing heating and cooling (if applicable) systems within the home. If the customer does not currently have cooling in the home but is looking for a cooling solution, the time of sale baseline described next should be used for the cooling load.

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	11.8[303]	8.2

Definition of Efficient Condition

The efficient condition is an ENERGY STAR ductless heat pump exceeding all of the following efficiency standards; 14.5 SEER, 12 EER, 8.2 HSPF.

Annual Energy Savings Algorithm

If displacing/replacing electric heat:

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[303] 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.

ΔkWH = Cooling savings from increased efficiency +
Electric heating savings from increased efficiency

= (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) +
(HeatLoadElectricDHP * (3.412/HSPFbase – 3.412/HSPFee)

If displacing/replacing gas heat:

ΔkWH = Cooling savings from increased efficiency -
New Electric heating load

= (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) - (HeatLoadGasDHP * 293.1 * 0.85 * (3.412/HSPFee)))

Where:

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

= Actual

SEERbase = Efficiency in SEER of existing Air Conditioner or baseline ductless heat pump

Early Replacement = Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 10.0[304] *for Central AC or 8.5 for Room AC*[305]*. If no cooling exists but the customer is looking for a cooling solution, assume 14.0. If no cooling exists or was planned at the home, make 1/SEER = 0 (resulting in a negative value i.e. increase in cooling load).*

Time of Sale / New Construction = 14.0[306]

SEERee = Efficiency in SEER of efficient ductless heat pump
= Actual

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[304] VEIC estimate based on Department of Energy Federal Standard between 1992 and 2006. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

[305] Estimated by converting the assumption of existing unit EER efficiency in the Room Air Conditioner Early Replacement measure (7.7EER) in to SEER using the assumption EER≈SEER/1.1.

[306] Minimum Federal Standard

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

= Actual[307]

3.412 = Converts 1/HSPF to 1/COP

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

Early Replacement = Use actual HSPF rating where it is possible to measure or reasonably estimate.
If unknown assume 3.412[308] *for resistance heat,* 5.96**[309]** for ASHP.

Time of Sale / New Construction = 8.2 [310]

HSPFee = Heating Seasonal Performance Factor of ENERGY STAR ductless heat pump[311]
= Actual

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

= Actual[312]

293.1 = Converts MMBtu to kWh

0.85 = Factor to reduce consumption by 15% to account for elimination of duct losses

AFUEexist = Efficiency of existing Furnace

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[307] For example with a Manual-J calculation or similar modeling.
[308] Assume COP of 1.0 converted to HSPF by multiplying by 3.412.
[309] 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 10.0.
[310] Minimum Federal Standard
[311] 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 geographical/climate variances.
[312] For example with a Manual-J calculation or similar modeling.

= *Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 78%*[313].

3.412 = *Converts heat pump HSPF in to COP*

See example calculations at end of characterization.

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = BTU/hour_{Cool} * (1/EERbase - 1/EERee))/1,000 * CF$$

Where:

BTU/hour$_{Cool}$ = *Cooling capacity of ductless heat pump (1 ton = 12,000BTU/hour)*
= *Actual*

EERbase = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*

Early Replacement = *Use actual EER rating where it is possible to measure or reasonably estimate.*
If unknown assume 9.1[314] *for Central AC or 7.7 for Room AC*[315].
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 = *11.8*[316]

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

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

[314] Based on converting the SEER 10 to EER using the assumption EER≈SEER/1.1.

[315] 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."

[316] The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (14) and equals EER 11.2. To perform this calculation we are using this formula: (-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).

= *Actual.*

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)*
= *0.31* [317]

$CF_{PJM\ Room\ AC}$ = *PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[318]

$CF_{SSP\ Central\ AC}$ = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [319]

$CF_{PJM\ Central\ AC}$ = *PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.66* [320]

See example calculations at end of characterization.

Annual Fossil Fuel Savings Algorithm

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

[318] 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).

[319] 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.

[320] 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.

If the existing heating system is gas fired, the savings from the measure represent the displaced gas heating consumption, and the DHP represents added electric load.

$$\Delta MMBtu = HeatLoadGasReplaced / AFUEexist$$

Where:

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

= Actual[321]

AFUEexist = Efficiency of existing heating system
= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 78%[322].

See example calculations at end of characterization.

Annual Water Savings Algorithm

n/a

Incremental Cost

Early Replacement: the actual full cost of the DHP installation should be used if available, if not defaults are provided in the table below:

Unit Size	Early Replacement: Full Install Cost[323]
1-Ton	$3,000
1.5-Ton	$3750
2-Ton	$4,500
2.5-Ton	$5,250

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

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

[323] Based upon review of *Ductless Heat Pumps for Residential Customers in Connecticut*, Swift, Joseph R and Rebecca A. Meyer, The Connecticut Light & Power Company, 2010 ACEEE Summer Study on Energy Efficiency in Buildings (2-292). Also supported by findings in NEEP *Northeast/Mid-Atlantic Air-Source Heat Pump Market Strategies Report,* January 2014 and NEEP *Incremental Cost Study Phase Two Final Report*, January 2013. If existing heating and cooling load is replaced at the end of its life, then a baseline cost should be determined and subtracted from the full install cost.

3-Ton	$6,000

If the DHP installation results in the early removal of existing operating heating or cooling equipment (that otherwise would have needed to be replaced in the future) then the deferred replacement of that equipment should be accounted for. This deferred replacement cost should be estimated based on the existing equipment or the following defaults can be used:

Central AC - $2,185 per ton[324].

Central Ducted Air Source Heat Pump - $2,166 per ton[325]

Furnace - $2,311 [326]

Boiler - $3,834 [327]

The deferred replacement cost should be discounted to today's dollar assuming it would have occurred in 6 years (3rd of measure life) and subtracted from the full DHP install cost presented above.

Time of Sale / New construction: an estimated incremental cost from a SEER 14 baseline is provided below:

Unit Size	Time of Sale / New Construction: Incremental Cost[328]
1-Ton	$603
1.5-Ton	$624
2-Ton	$601
2.5-Ton	$600
3-Ton	$600

---

[324] Costs based upon average cost per ton for Equipment and Labor from Itron Measure Cost Study Results Matrix Volume 1 (part of "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014).

[325] Ibid.

[326] Boiler and Furnace Costs derived from Page E-3 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document: http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html. Plus $300 labor estimate based on Itron Measure Cost Study Results Matrix Volume 1.

[327] Ibid. Labor estimated as $500.

[328] Incremental costs against a SEER 13 mini-split as presented in NEEP *Incremental Cost Study Phase Two Final Report*, January 2013. Results for 1 and 1.5 ton are based upon 21 SEER (most represented) and 18 SEER for 2 ton (only value provided). Values for 2.5 and 3 ton are assumed consistent with the other sizes.

Measure Life

The measure life is assumed to be 18 years[329]. 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

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[329] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://library.cee1.org/content/measure-life-report-residential-and-commercialindustrial-lighting-and-hvac-measures

Illustrative examples – do not use as default assumption

Early Replacement:

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

ΔkWH = (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) + (HeatLoadElectricDRP * (3.412/HSPFbase – 3.412/HSPFee)

= (2000 * (0 – 1/20)) + (5000 * (3.412/3.4 – 3.412/12))

= 3,496 kWh

ΔkW_{SSP} = BTU/$hour_{Cool}$ * (1/EERbase - 1/EERee))/1,000 * CF

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

= - 0.40kW

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.

ΔkWH = (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) - (HeatLoadGasDHP * 293.1 * 0.85 * (3.412/HSPFee))

= (4000 * (1/10 – 1/18)) - (40 * 293.3 * 0.85 * (3.412/11))

= -2,915 kWh (i.e. this results in an increase in electric consumption)

ΔkW_{SSP} = BTU/$hour_{Cool}$ * (1/EERbase - 1/EERee))/1,000 * CF

= (30,000 * (1/9.1 – 1/13.5)) / 1000) * 0.31

= 0.33 kW (in the summer you see demand savings)

ΔMMBtu = HeatLoadGasReplaced / AFUEexist

= 40 / 0.78

= 51.3 MMBtu

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

ΔkWH = (CoolingLoadDHP * (1/SEERbase - 1/SEERee)) + (HeatLoadElectricDHP * (3.412/HSPFbase – 3.412/HSPFee)

= (6000 * (1/14 – 1/18)) + (12,000 * (3.412/8.2– 3.412/11))

= 1,366kWh

ΔkW_{SSP} = $BTU/hour_{Cool}$ * (1/EERbase - 1/EERee))/1,000 * CF

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

= 0.12 kW

HE Gas Boiler*

Unique Measure Code: RS_HV_TOS_GASBLR_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure characterization provides savings for the purchase and installation of a new residential sized ENERGY STAR-qualified high efficiency gas-fired boiler for residential space heating, instead of a new baseline gas boiler. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

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

Definition of Baseline Condition

The baseline condition is a boiler that meets the minimum Federal baseline AFUE for boilers. For boilers manufactured after September 2012, the Federal baseline is 82% AFUE.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified boiler with an AFUE rating ≥ 85%.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = (EFLHheat * BTU/hour * ((AFUEee/AFUEbase) - 1)) /1,000,000$$

Where:

EFLHheat = Equivalent Full Load Heating Hours

Location	*EFLH*
Wilmington, DE	*848*[330]
Baltimore, MD	*620*[331]
Washington, DC	*528*[332]

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

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

$$\Delta MMBtu = (620 * 100{,}000 * ((0.9/0.82) - 1)) / 1{,}000{,}000$$

$$= 6.0 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental install cost for this measure is provided below[333]:

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[330] 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

[331] 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.

[332] 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.

[333] Costs derived from Page E-13 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf
VEIC believes it is reasonable to assume that the cost provided from this study for an 85% unit is appropriate for units in the 85-90% AFUE range and the cost for the 91% unit can be used for 91+% units. This is based on the observation that most of the products available in the 85-90 range are in the lower end of the range, as are those units available above 91% AFUE.

Efficiency of Boiler (AFUE)	Incremental Cost
85% - 90%	$725
91% +	$1272

Measure Life

The measure life is assumed to be 18 years[334] .

Operation and Maintenance Impacts

n/a

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[334] 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

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%[335].

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

n/a. Note, if the furnace has an ECM fan, electric savings should be claimed as characterized in the “Central Furnace Efficient Fan Motor” section of the TRM.

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = (EFLHheat * BTU/hour * ((AFUEee/AFUEbase) - 1) /1,000,000$$

Where:

EFLHheat = *Equivalent Full Load Heating Hours*

---

[335] The Federal baseline for furnaces is actually 78%, although it becomes 80% in November 2015. Experience suggests a suitable market baseline is 80% AFUE.

Location	*EFLH*
Wilmington, DE	*848*[336]
Baltimore, MD	*620*[337]
Washington, DC	*528*[338]

BTU/hour = *Input Capacity of Furnace*
= *Actual*

AFUEbase = *Efficiency in AFUE of baseline Furnace*
= *0.80*

AFUEee = *Efficiency in AFUE of efficient Furnace*
= *Actual*

Illustrative example – do not use as default assumption
The purchase and installation of a 100,000 BTU/hour, 92% AFUE furnace in Maryland:

ΔMMBtu = (620 * 100,000 * ((0.92/0.8) – 1) /1,000,000

= 9.3 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below[339]:

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[336] 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

[337] 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.

[338] 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.

[339] Costs derived from Page E-3 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document: http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html

Efficiency of Furnace (AFUE)	Incremental Cost
90%	$630
92%	$802
96%	$1,747

Measure Life

The measure life is assumed to be 18 years[340].

Operation and Maintenance Impacts

n/a

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[340] 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

Programmable Thermostat

Unique Measure Code: RS_HV_RTR_PRGTHE_0711
Effective Date: June 2014
End Date: TBD

Measure Description

Programmable Thermostats can save energy through the advanced scheduling of setbacks to heating setpoints. Typical usage reduces the heating setpoint during times of the day when occupants are usually not at home (e.g. work hours) or during the night.

Note, savings are only provided for the reduction in heating load for fossil fuel fired heating systems. A literature review could not find any appropriate defensible source of cooling savings from programmable thermostats. It is inappropriate to assume a similar pattern of savings from setting your thermostat down during the heating season and up during the cooling season.

This is a retrofit measure.

Definition of Baseline Condition

A standard, non-programmable thermostat for central heating system (baseboard electric is excluded from this characterization).

Definition of Efficient Condition

A programmable thermostat is installed and programmed by a professional.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = (Savings\ \%) \times (Heat\ Consumption)$$

Where:

Savings % = *Estimated percent reduction in heating load due to programmable thermostat*

= *6.8%* [341]

Heat Consumption = *Annual Home Heating* Consumption *(MMBtu)*

= *50.1* [342]

ΔMMBtu = 0.068 * 50.1

= 3.41 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual unit cost and if installed via program administrators should also include labor cost[343].

Measure Life

The measure life is assumed to be 10 years[344].

Operation and Maintenance Impacts

n/a

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[341] 2007, RLW Analytics, “Validating the Impact of Programmable Thermostats”

[342] 50.1 MMBtu heating consumption is estimated based on the MD Residential Baseline Database, subtracting Base load from Base + Heat.

[343] The range of costs observed in VEIC’s review of other utilities TRMs was $35-$40 for the unit, $100 for labor. In the absence of actual program costs, this cost could be used.

[344] 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

Room Air Conditioner Early Replacement

Unique Measure Code: RS_HV_RTR_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.

This is a retrofit measure.

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 10.9EER[345]).

Definition of Efficient Condition

The efficient condition is a new replacement room air conditioning unit meeting the ENERGY STAR efficiency standard (i.e. with an efficiency rating greater than or equal to 11.3 [346]).

Annual Energy Savings Algorithm

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

$\Delta kWh = (Hours * BTU/hour * (1/EERexist - 1/EERee))/1,000$

Savings for remaining measure life (next 9 years)

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

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

ΔkWh = (Hours * BTU/hour * (1/EERbase - 1/EERee))/1,000

Where:

Hours = *Run hours of Window AC unit*
= *325* [347]
BTU/hour = *Capacity of replaced unit*
= *Actual or 8,500 if unknown* [348]
EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *7.7* [349]
EERbase = *Efficiency of baseline unit in Btus per Watt-hour*
= *10.9* [350]
EERee = *Efficiency of ENERGY STAR unit in Btus per Watt-hour*
= *Actual*

Illustrative example – do not use as default assumption
Replacing existing 8,500 BTU/hour Room AC unit with a new ENERGY STAR unit with EER rating of 11.3:

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

ΔkWh = (325 * 8,500 * (1/7.7– 1/11.3)) / 1,000

= 114 kWh

Savings for remaining measure life (next 9 years)

ΔkWh = (325 * 8,500 * (1/10.9 – 1/11.3)) / 1,000

= 9 kWh

Summer Coincident Peak kW Savings Algorithm

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

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[347] 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.

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

[349] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

[350] Minimum Federal Standard for capacity range.

$\Delta kW = ((BTU/hour * (1/EERexist - 1/EERee))/1000) * CF$

Savings for remaining measure life (next 9 years)

$\Delta kW = ((BTU/hour * (1/EERbase - 1/EERee))/1000) * CF$

Where:

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

= *0.31* [351]

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

= *0.3*[352]

Illustrative example – do not use as default assumption
Replacing existing 8,500 BTU/hour Room AC unit with a new ENERGY STAR unit with EER rating of 11.3.

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

ΔkW_{SSP} = ((8,500 * (1/7.7 – 1/11.3)) / 1,000) * 0.31

= 0.11 kW

Savings for remaining measure life (next 9 years)

ΔkW_{SSP} = ((8,500 * (1/10.9 – 1/11.3)) / 1,000) * 0.31

= 0.0086 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual cost of the replacement unit and any cost of installation labor.

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

[352] 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).

Note, the deferred baseline replacement cost is presented under Operation and Maintenance Impacts.

Measure Life

The measure life is assumed to be 12 years[353]. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced[354].

Operation and Maintenance Impacts

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

$NPV_{\text{deferred replacement cost}}$ = (Actual Cost of ENERGY STAR unit - $40[355]) * 69%[356].

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

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[353] 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

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

[355] Incremental cost of ENERGY STAR unit over baseline unit; consistent with Time of Sale Room AC measure.

[356] 69% is the ratio of 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. The calculation is done in this way to allow the use of the known ENERGY STAR replacement cost to calculate an appropriate baseline replacement cost.

Room Air Conditioner Early Retirement / Recycling

Unique Measure Code: RS_HV_ERT_RA/C_0414
Effective Date: June 2014
End Date: TBD

Measure Description

This measure describes the savings resulting from implementing a drop off service taking existing working inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that a percentage of these units will ultimately be replaced with a baseline standard efficiency unit (note that if it is actually replaced by a new ENERGY STAR qualifying unit, the savings increment between baseline and ENERGY STAR should be captured under the ENERGY STAR Room AC Time of Sale measure).

Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit.

Definition of Efficient Condition

Not applicable. This measure relates to the retiring of an existing inefficient unit. A percentage of units however are assumed to be replaced with a baseline new unit and the savings are therefore reduced to account for these replacement units.

Annual Energy Savings Algorithm

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

Where:

Hours = *Run hours of Window AC unit*
= *325* [357]
BTU/hour = *Capacity of replaced unit*
= *Actual or 8,500 if unknown* [358]

---

[357] 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.

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

EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *Actual or 7.7 if unknown* [359]
%replaced = Percentage of units dropped off that are replaced in the home
= 76% [360]
EERnewbase = *Efficiency of new baseline unit in Btus per Watt-hour*
= 10.9[361]

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

$$\Delta kWh = ((325 * 8{,}500 * (1/7.7))/1{,}000) - (0.76 * ((325 * 8{,}500 * (1/10.9))/1{,}000)$$

$$= 166\ kWh$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((BTU/hour * (1/EERexist))/1{,}000) - (\%replaced * ((BTU/hour * (1/EERnewbase))/1{,}000) * CF$$

Where:
CF_{SSP} = *Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [362]
CF_{PJM} = *PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[363]

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[359] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

[360] 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.

[361] 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.

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

[363] 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).

Illustrative example – do not use as default assumption
The turn in of an 8500 BTU/hour, 7.7 EER unit:

$$\Delta kW_{SSM} = ((8{,}500 * (1/7.7))/1{,}000) - (0.76 * ((8{,}500 * (1/10.9))/1{,}000) * 0.31$$

$$= 0.16 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual implementation cost for recycling the existing unit, plus $129 to account for the replacement of 76% of the units[364].

Measure Life

The measure life is assumed to be 3 years[365].

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 have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $89.36[366].

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[364] $129 replacement cost is calculated by multiplying the percentage assumed to be replaced – 76% by the assumed cost of a standard efficiency unit of $170 (ENERGY STAR calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls); 0.76 * 170 = $129.2.

[365] 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

[366] 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_RTR_PIPEIN_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes adding insulation to un-insulated boiler pipes in un-conditioned basements or crawlspaces.

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

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is an un-insulated boiler pipe.

Definition of Efficient Condition

The efficient condition is installing pipe wrap insulation to a length of boiler pipe.

Annual Energy Savings Algorithm

N/A

Summer Coincident Peak kW Savings Algorithm

N/A

Annual Fossil Fuel Savings Algorithm

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

Where:

R_{exist} = *Pipe heat loss coefficient of uninsulated pipe [(hr-°F-ft^2)/Btu]*
= *0.5*[367]

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

EFLH_heat = *Equivalent Full load hours of heating*

---

[367] 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.

Location	EFLH
Wilmington, DE	*848* [368]
Baltimore, MD	*620* [369]
Washington, DC	*528* [370]

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

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

C_{new} = *Circumference of pipe with insulation(ft) (Diameter (in) * π/12)*
= *Actual*

ΔT = *Average temperature difference between circulated heated water and unconditioned space air temperature (°F)* [371]

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

ηBoiler = *Efficiency of boiler*
= *0.8* [372]

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:

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[368] 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

[369] 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.

[370] 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.

[371] 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).

[372] Assumed efficiency of existing boilers.

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

$= (((1/0.5 * 0.196) – (1/3.5 * ((0.75+0.75+0.75) * \pi/12))) * 848 * 15 * 120) / 0.8 / 1,000,000$

= 0.43 MMBtu

Annual Water Savings Algorithm

N/A

Incremental Cost

The measure cost including material and installation is assumed to be $3 per linear foot[373].

Deemed Lifetime of Efficient Equipment

The assumed lifetime of the measure is 15 years[374].

Operation and Maintenance Impacts

N/A

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

[374] 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

Boiler Reset Controls**

Unique Measure Code: RS_HV_TOS_BLRRES_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.

Definition of Baseline Condition

Existing condensing boiler in a single family residential setting without boiler reset controls.

Definition of Efficient Condition

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer’s recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single family residence. Boiler reset controls for non-condensing boilers in single family 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

ΔMMBtu = (Savings %) * (EFLHheat * BTU/hour)/ 1,000,000

Where:

Savings % = *Estimated percent reduction in heating load due to boiler reset controls being installed*
= *5%*[375]

EFLHheat = *Equivalent Full Load Heating Hours*

Location	*EFLH*
Wilmington, DE	*848*[376]
Baltimore, MD	*620*[377]
Washington, DC	*528*[378]

BTU/hour = *Input Capacity of Boiler*
= *Actual*

Illustrative example – do not use as default
A boiler reset control is applied to a 80,000 BTU/hour boiler in Baltimore, MD.

ΔMMBtu = 0.05 * (620 * 80,000)/1,000,000

= 2.48 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

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[375] 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://www.cleanboiler.org/Eff_Improve/Efficiency/Boiler_Reset_Control.asp

[376] 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

[377] 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.

[378] 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.

The cost of this measure is \$612[379]

Measure Life

The life of this measure is 20 years[380]

Operation and Maintenance Impacts

n/a

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

[380] The Brooklyn Union Gas Company d/b/a National Grid NY Case 08-G-1016 High-Efficiency Heating and Water Heating and Controls Gas Energy Efficiency Program Implementation Plan, P 37 https://www.nationalgridus.com/non_html/eer/nydown/NYC%20Expedited%20Program%20Implementation%20Plan.pdf

Ground Source Heat Pumps**

Unique Measure Code: RS_HV_TOS_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 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
DGX	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

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 11.8[381] EER. If a

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[381] 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.

desuperheater is installed, the baseline for DHW savings is assumed to be a Federal Standard electric hot water heater, with Energy Factor calculated as follows[382]:

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

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

Time of Sale:

The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8 EER. If a desuperheater is installed, the baseline for DHW savings is assumed to be the existing home's hot water heater fuel and efficiency.

If electric DHW, and unknown efficiency – assume efficiency is equal to pre 4/2015 Federal Standard:

EF = 0.93 – (0.00132 * rated volume in gallons)[383]

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:

EF = (0.67 – 0.0019 * rated volume in gallons)[384].

If size is unknown, assume 40 gallon; 0.594 EF

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

ΔkWh = [Cooling savings] + [Heating savings] + [DHW savings]

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[382] 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

[383] 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

[384] 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

$$= [(FLHcool * Capacity\_cooling * (1/SEER_{base}– (1/EER_{PL})/1000] + [FLHheat * Capacity\_heating * (1/HSPF_{base} – (1/COP_{PL} * 3.412)))/1000] + [ElecDHW * \%DHWDisplaced * (((1/EF_{ELEC}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} – T_{IN}) * 1.0) / 3412)]$$

Where:

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

Location	*Run Hours*
Wilmington, DE	*524* [385]
Baltimore, MD	*542* [386]
Washington, DC	*681*

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

SEERbase = SEER Efficiency of new replacement baseline unit
= 14[387]

EER_{PL} = Part Load EER Efficiency of efficient GSHP unit[388]
= Actual installed

FLHheat = Full load heating hours

Location	*EFLH*
Wilmington, DE	*848*[389]
Baltimore, MD	*620*[390]

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[385] 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)

[386] 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.

[387] 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

[388] 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.

[389] 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

[390] 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",

Washington, DC	*528*[391]

Capacity_heating =Heating Capacity of Ground Source Heat Pump (BTU/hour)
=Actual (1 ton = 12,000BTU/hour)

$HSPF_{base}$ *=Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)*
=8.2 [392]

COP_{PL} *= Part Load Coefficient of Performance of efficient unit*[393]
= Actual Installed

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

ElecDHW = 1 if existing DHW is electrically heated
= 0 if existing DHW is not electrically heated

%DHWDisplaced = Percentage of total DHW load that the GSHP will provide
= Actual if known
= If unknown and if desuperheater installed assume 44%[394]
= 0% if no desuperheater installed

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

For new construction assume federal standard[395]*:*
*For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)*
*For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)*

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

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

[391] 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.

[392] 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

[393] 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.

[394] 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.

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

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

*EF = 0.93 – (0.00132 * rated volume in gallons)*[396]

If size is unknown, assume 50 gallon; 0.864 EF

GPD = Gallons Per Day of hot water use per person
= 45.5 gallons hot water per day per household/2.59 people per household[397]
= 17.6

Household = Average number of people per household

= 2.53 [398]

365.25 = Days per year

γWater = Specific weight of water
= 8.33 pounds per gallon

T_{OUT} *= Tank temperature*
= 125°F

T_{IN} *= Incoming water temperature from well or municipal system*
= 60.9 [399]

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

3412 = Conversion from Btu to kWh

Illustrative Example – do not use as default assumption

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[396] 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

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

[398] 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

[399] 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.

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:

$$\Delta\text{kWh} = [(\text{FLHcool} * \text{Capacity\_cooling} * (1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}})/1000] + [(\text{FLHheat} * \text{Capacity\_heating} * (1/\text{HSPFbase} - (1/\text{COP}_{\text{PL}} * 3.412)))/1000] + [\text{ElecDHW} * \%\text{DHWDisplaced} * (((1/ \text{EF}_{\text{ELEC EXIST}}) * \text{GPD} * \text{Household} * 365.25 * \gamma\text{Water} * (\text{T}_{\text{OUT}} - \text{T}_{\text{IN}}) * 1.0) / 3412)]$$

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

$$= 367 + 1235 + 1185$$

$$= 2787 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta\text{kW} = (\text{Capacity\_cooling} * (1/\text{EERbase} - 1/\text{EER}_{\text{FL}}))/1000) * \text{CF}$$

Where:

EERbase = *EER Efficiency of new replacement unit*
= *11.8*[400]

EER_{FL} = *Full Load EER Efficiency of ENERGY STAR GSHP unit* [401]
= *Actual*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [402]

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*

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

[401] 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.

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

= 0.66 [403]

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:

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

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

Annual Fossil Fuel Savings Algorithm

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

ΔMMBtu = [DHW Savings]

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

Where:

$EF_{GAS\ EXIST}$ = Energy Factor (efficiency) of existing gas water heater
= Actual. If unknown assume efficiency is equal to pre 4/2015 Federal Standard:
*= (0.67 – 0.0019 * rated volume in gallons)*[404].

If size is unknown, assume 40 gallon; 0.594 EF

All other variables provided above

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[403] 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.

[404] 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

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:

$$\Delta MMBtu = [(1 - ElecDHW) * \%DHWDisplaced * (1/ EF_{GAS\ BASE} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 1{,}000{,}000)]$$

$$= [(1 - 0) * 0.44 * (((1/0.594) * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1)/1{,}000{,}000)]$$

$$= 6.4 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton[405]), minus the assumed installation cost of the baseline equipment ($2355 per ton for ASHP[406]).

Measure Life

The expected measure life is assumed to be 25 years[407].

Operation and Maintenance Impacts

N/A

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

[406] Based upon average cost per ton for Equipment and Labor for SEER 14 ASHP from Itron Measure Cost Study Results Matrix Volume 1 (part of "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014).

[407] System life of indoor components as per DOE estimate http://energy.gov/energysaver/articles/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

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 50 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

Definition of Baseline Condition

New standard efficiency (average CFM/Watt of 3.1[408]) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[409].

Definition of Efficient Condition

New efficient (average CFM/watt of 8.3[410]) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2[411]

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[408] 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.

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

[410] 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.

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

Annual Energy Savings Algorithm

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

Where:

CFM = Nominal Capacity of the exhaust fan
= 50 CFM[412]
ηBaseline = Average efficacy for baseline fan
= 3.1 CFM/Watt[413]
ηEffcient = Average efficacy for efficient fan
= 8.3 CFM/Watt[414]
Hours = assumed annual run hours,
= 8766 for continuous ventilation.

$$\Delta kWh = (50 * (1/3.1 – 1/8.3)/1000) * 8766$$
$$= 88.6 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

Other variables as defined above

$$\Delta kW = (50 * (1/3.1 – 1/8.3)/1000) * 1.0$$
$$= 0.0101 \text{ kW}$$

Deemed Lifetime of Efficient Equipment

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[412] 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.

[413] 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.

[414] 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.

The expected measure life is assumed to be 19 years[415].

Deemed Measure Cost

Incremental cost per installed fan is $43.50 for quiet, efficient fans[416].

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[415] 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.

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

ENERGY STAR Ceiling Fan**

Unique Measure Code: RS_HV_TOS_ESCFN_0415, RS_HV_NC_ESCFN_0415
Effective Date: June 2015
End Date: TBD

Measure Description

A ceiling fan/light unit meeting the ENERGY STAR efficiency specifications is installed in place of a model meeting the federal standard. ENERGY STAR qualified ceiling fan/light combination units are over 60% more efficient than conventional fan/light units, and use improved motors and blade designs[417].

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

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[417] http://www.energystar.gov/products/certified-products/detail/ceiling-fans

Where[418]*:*

Days = *Days used per year*
= *Actual. If unknown use 365.25 days/year*

FanHours = *Daily Fan "On Hours"*
= *Actual. If unknown use 3 hours*

$\%Low_{base}$ = *Percent of time spent at Low speed of baseline*
= *40%*

$WattsLow_{base}$ = *Fan wattage at Low speed of baseline*
= *Actual. If unknown use 15 watts*

$\%Med_{base}$ = *Percent of time spent at Medium speed of baseline*
= *40%*

$WattsMed_{base}$ = *Fan wattage at Medium speed of baseline*
= *Actual. If unknown use 34 watts*

$\%High_{base}$ = *Percent of time spent at High speed of baseline*
= *20%*

$WattsHigh_{base}$= *Fan wattage at High speed of baseline*
= *Actual. If unknown use 67 watts*

%LowES = *Percent of time spent at Low speed of ENERGY STAR*
= *40%*

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

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

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

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

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[418] All fan default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan Savings Calculator; http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?8178-e52c

= 20%

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

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

	Low Speed	*Medium Speed*	*High Speed*
Percent of Time at Given Speed	*40%*	*40%*	*20%*
Conventional Unit Wattage	*15*	*34*	*67*
ENERGY STAR Unit Wattage	*6*	*23*	*56*
ΔW	*9*	*11*	*11*

If the lighting WattsBase and WattsEE is unknown, assume the following
WattsBase = 3 x 43 = 129 W

WattsEE = 1 x 42 = 42 W

Deemed savings if using defaults provided above:

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

ΔkWh_{light} =((129 – 42)/1000) * 1.0 * 898 * (0.894 + (1.09-1))
= 76.9 kWh

ΔkWh = 11.2 + 76.9

= 88.1 kWh

Summary Coincident Peak kW Savings Algorithm

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

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

$\Delta kW_{Light} = ((WattsBase - WattsEE) /1000) * ISR * WHFd * CFlight$

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

Where:

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

= 0.31 [419]

$CFfan_{PJM}$ *= PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= 0.3[420]

CFlight *= Summer Peak coincidence factor for lighting savings*

Installation Location	Type	Coincidence Factor CF
Residential interior and in-unit Multi Family	Utility Peak CF	0.082[421]
	PJM CF	0.084[422]

Deemed savings if using defaults provided above:

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

$\Delta kW_{light\ ssp}$ =((129 – 42)/1000) * 1.0 * 1.18 * 0.073
= 0.0075 kW

ΔkW_{ssp} = 0.0034 + 0.0075
= 0.011 kW

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

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

ΔkW_{pjm} = 0.0033 + 0.0086
= 0.012 kW

Annual Fossil Fuel Savings Algorithm

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[419] 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.

[420] Assuming that the CF for a ceiling fan is the same as Room AC; 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).

[421] Based on EmPOWER_EY5 Deemed Savings Recommendations_20Jan2015 DRAFT.

[422] Ibid.

Heating penalty from improved lighting:

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

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

Deemed savings if using defaults provided above:

$$\Delta MMBtuPenalty = - ((((129 – 42) / 1000) * 1.0 * 898 * 0.47 * 0.003412) / 0.72) * 0.625$$

$$= -0.11$$

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental cost of unit is assumed to be \$46.[423]

Measure Life

The fan savings measure life is assumed to be 10 years.[2]

The lighting savings measure life is assumed to be 5 years as per General Purpose CFL Screw Based, Residential measure.

Operation and Maintenance Impacts

See General Purpose CFL Screw Based, Residential measure.

Deemed baseline O&M cost if using defaults provided above:

Year	NPV of baseline Replacement Costs Per bulb	Total NPV of baseline Replacement Costs (assuming 3 bulbs)
2015	$3.83	$11.49
2016	$2.94	$8.82
2017	$2.01	$6.03

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[423] ENERGY STAR Ceiling Fan Savings Calculator http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?8178-e52c

Domestic Hot Water (DHW) End Use

Low Flow Shower Head

Unique Measure Code(s): RS_WT_INS_SHWRHD_0414 and 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 showerhead using rated GPM of installed showerhead. If actual flow rates of baseline is used in a direct install program then actual flow rate of the installed efficient showerhead should be used.

Annual Energy Savings Algorithm

If electric domestic water heater:

ΔkWH[424] = ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year) / SH/home * 8.3 * (TEMPsh - TEMPin) / 1,000,000) / DHW Recovery Efficiency / 0.003412

Where:

GPMbase = Gallons Per Minute of baseline showerhead
= 2.5 [425] *or actual flow rate if recorded*

GPMlow = Gallons Per Minute of low flow showerhead
= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.

---

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

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

 # people = Average number of people per household
= 2.56 [426]
gals/day = Average gallons per day used for showering
= 11.6 [427]
days/y = Days shower used per year
= 365
Showers/home = Average number of showers in the home
= 1.6 [428]
8.3 = Constant to convert gallons to lbs
TEMPsh = Assumed temperature of water used for shower
= 105 **Error! Bookmark not defined.**
TEMPin = Assumed temperature of water entering house
= 60.9 [429]
DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [430]
0.003412 = Constant to convert MMBtu to kWh

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

ΔkWH = ((((2.5 – 2.0) / 2.5) *2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-60.9) / 1,000,000) / 0.98 / 0.003412

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

[427] 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)

[428] 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" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

[429] 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.

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

= 148 kWh

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

Summer Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Average number of hours per year spent using shower head*
= *(Gal/person * # people * 365) / SH/home / GPM / 60*
= *(11.6 * 2.56 * 365) / 1.6 / 2.5 / 60*
= *45 hours*

CF = *Summer Peak Coincidence Factor for measure*
= *0.00371* [431]

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

$$\Delta kW = 148 / 45 * 0.00371$$

$$= 0.0122 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater:

$$\Delta MMBtu = ((((GPMbase - GPMlow) / GPMbase) * \# people * gals/day * days/year)) / SH/home * 8.3 * (TEMPsh - TEMPin) / 1{,}000{,}000) / Gas\ DHW\ Recovery\ Efficiency$$

Where:

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[431] 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 minutes per day (11.6 * 2.56 / 1.6 / 2.5 = 7.42) = 0.668 minutes
= 0.668 / 180 (minutes in peak period) = 0.00371

Gas DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.75* [432]
All other variables *As above*

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

ΔMMBtu = ((((2.5 – 2.0) / 2.5) * 2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-60.9) / 1,000,000) / 0.75

= 0.661 MMBtu

Annual Water Savings Algorithm

Water Savings = (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year) / 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:

Water Savings = ((((2.5 – 2.0) / 2.5) * 2.56 * 11.6 * 365)) / 1.6 / 748

= 1.81 CCF

kWh Savings from Water Reduction

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

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[432] 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%.

ΔkWh_{water}[433] $= 2.07\ kWh * \Delta Water\ (CCF)$

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

$$\Delta kWh_{water} = 2.07 * 1.81$$
$$= 3.7kWh$$

Incremental Cost

As a retrofit measure, the incremental cost will be the actual cost of installing the new showerhead. As a time of sale measure, the incremental cost is assumed to be $6.[434]

Measure Life

The measure life is assumed to be 10 years.[435]

Operation and Maintenance Impacts

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

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[433] 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.

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

[435] 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://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf)

Faucet Aerators

Unique Measure Code(s): RS_WT_INS_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 baseline is used in a direct install program then actual flow rate of the installed aerator should be used.

Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta kWH^{436} = (((((GPMbase - GPMlow) / GPMbase) * \# people * gals/day * days/year * DR) / (F/home)) * 8.3 * (TEMPft - TEMPin) / 1{,}000{,}000) / DHW Recovery Efficiency / 0.003412$$

Where:

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [437] *or actual flow rate if recorded*

---

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

[437] 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.

GPMlow = *Gallons Per Minute of low flow faucet*
= *Rated flow rate of unit installed or actual flow rate if baseline flow rate used.*
 # people = *Average number of people per household*
= *2.56* [438]
gals/day = *Average gallons per day used by faucet*
= *10.9* [439]
days/y = *Days faucet used per year*
= *365*
DR = *Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)*
= *50%* [440]
F/home = *Average number of faucets in the home*
= *3.5* [441]
8.3 = *Constant to convert gallons to lbs*
TEMPft = *Assumed temperature of water used by faucet*
= *80* **Error! Bookmark not defined.**
TEMPin = *Assumed temperature of water entering house*
= *60.9* [442]
DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.98* [443]
0.003412 = *Constant to converts MMBtu to kWh*

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

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

[439] 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)

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

[441] 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

[442] 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.

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

ΔkWH = ((((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

= 22 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

ΔkW = ΔkWh/hours * CF

Where:

Hours = *Average number of hours per year spent using faucet*
= *(Gal/person * # people * 365) /(F/home) / GPM / 60*
= *(10.9 * 2.56 * 365) / 3.5 / 2.2 / 60*
= *22 hours*

CF = *Summer Peak Coincidence Factor for measure*
= *0.00262* [444]

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

ΔkW = 22 / 22 * 0.00262

= 0.0026 kW

Annual Fossil Fuel Savings Algorithm

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

ΔMMBtu = ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / (F/home) * 8.3 * (TEMPft - TEMPin) / 1,000,000) / Gas DHW Recovery Efficiency

Where:

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[444] 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

Gas DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.75* [445]
All other variables *As above*

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

$$\Delta MMBtu = ((((2.2 – 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80-60.9) / 1{,}000{,}000) / 0.75$$

$$= 0.098 \text{ MMBtu}$$

Annual Water Savings Algorithm

Water Savings = (((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year * DR) / (F/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 1.5 GPM rated aerator:

Water Savings = (((2.2 – 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 / 748

= 0.619 CCF

kWh Savings from Water Reduction

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

ΔkWh_{water}[446] = 2.07 kWh * ΔWater (CCF)

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[445] 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%.

[446] 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.

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

ΔkWh_{water} = 2.07 * 0.619
= 1.3 kWh

Incremental Cost

As a retrofit measure, the incremental cost will be the actual cost of installing the new aerator. As a time of sale measure, the incremental cost is assumed to be $2.[447]

Measure Life

The measure life is assumed to be 5 years.[448]

Operation and Maintenance Impacts

When a retrofit measure, there would be a very small O&M benefit associated with the deferral of the next replacement, but this has conservatively not been characterized.

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[447] Navigant Consulting, Ontario Energy Board, “Measures and Assumptions for Demand Side Management (DSM) Planning”, April 2009.
[448] Conservative estimate based on review of TRM assumptions from other States.

Domestic Hot Water Tank Wrap

Unique Measure Code(s): RS_WT_INS_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

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

Where:

ΔkWh = gross customer annual kWh savings for the measure

U_{base} = Overall heat transfer coefficient prior to adding tank wrap (BTU/hour-F-ft^2)
= See table below. If unknown assume 1/8 [449]

Uinsul = Overall heat transfer coefficient after addition of tank wrap (BTU/hour-F-ft2)
= See table below. If unknown assume 1/18 [450]

A_{base} = Surface area of storage tank prior to adding tank wrap (square feet)

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

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

= See table below. If unknown assume 23.18 [451]

A_{insul} *= Surface area of storage tank after addition of tank wrap (square feet)*

= See table below. If unknown assume 25.31 [452]

ΔT *= Average temperature difference between tank water and outside air temperature (°F)*

= 60°F [453]

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

= 8760

3412 *= Conversion from BTU to kWh*

ηDHW *= Recovery efficiency of electric hot water heater*

= 0.98 [454]

The following table has default savings for various tank capacity and pre and post R-VALUES.

Capacity (gal)	Rbase	Rinsul	Abase (ft2)	Ainsul (ft2)	ΔkWh	ΔkW
30	8	16	19.16	20.94	171	0.019
30	10	18	19.16	20.94	118	0.014
30	12	20	19.16	20.94	86	0.010
30	8	18	19.16	20.94	194	0.022
30	10	20	19.16	20.94	137	0.016
30	12	22	19.16	20.94	101	0.012
40	8	16	23.18	25.31	207	0.024
40	10	18	23.18	25.31	143	0.016
40	12	20	23.18	25.31	105	0.012
40	8	18	23.18	25.31	234	0.027
40	10	20	23.18	25.31	165	0.019
40	12	22	23.18	25.31	123	0.014
50	8	16	24.99	27.06	225	0.026
50	10	18	24.99	27.06	157	0.018
50	12	20	24.99	27.06	115	0.013

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[451] Assumptions from PA TRM for 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.

[452] Ibid.

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

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

50	8	18	24.99	27.06	255	0.029
50	10	20	24.99	27.06	180	0.021
50	12	22	24.99	27.06	134	0.015
80	8	16	31.84	34.14	290	0.033
80	10	18	31.84	34.14	202	0.023
80	12	20	31.84	34.14	149	0.017
80	8	18	31.84	34.14	327	0.037
80	10	20	31.84	34.14	232	0.027
80	12	22	31.84	34.14	173	0.020

If tank specifics are unknown assume 40 gallons as an average tank size[455], and savings from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kWh = ((23.18/8 - 25.31/18) * 60 * 8760) / (3412 * 0.98)$$

$$= 234 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/8760$$

Where:

ΔkWh = kWh savings from tank wrap installation

8760 = Number of hours in a year (since savings are assumed to be constant over year).

The table above has default savings for various tank capacity and pre and post R-VALUES.

If tank specifics are unknown assume 40 gallons as an average tank size[456], and savings are from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kW = 234 / 8760$$

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[455] 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

[456] 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

= 0.027 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure will be the actual cost of installing the tank wrap. If unknown assume $35 average cost[457].

Measure Life

The measure life is assumed to be 5 years.[458]

Operation and Maintenance Impacts

n/a

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[457] Based on VEIC online product review.

[458] 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_RTR_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

<u>If electric domestic hot water tank:</u>

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

Where:

Rexist = *Assumed R-value of existing uninsulated piping*
= *1.0* [459]

Rnew = *R-value of existing pipe plus installed insulation*
= *Actual*

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[459] 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.ontarioenergyboard.ca/oeb/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

Length = *Length of piping insulated*
= *Actual*
Circumference = *Circumference of piping*
= *Actual (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)*
ΔT = *Temperature difference between water in pipe and ambient air*
= *65°F* [460]
8,760 = *Hours per year*
ηDHW = *DHW Recovery efficiency (ηDHW)*
= *0.98* [461]
3413 = *Conversion from Btu to kWh*

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

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

$$= 104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

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

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

$$= 0.012 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

If fossil fuel DHW unit:

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

---

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

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

Where:

ηDHW = Recovery efficiency of gas hot water heater
= 0.75 [462]

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

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

$$= 0.46 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual cost of material and labor. If this is not available, assume $3 per foot of insulation[463].

Measure Life

The measure life is assumed to be 15 years[464].

Operation and Maintenance Impacts

n/a

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[462] 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%

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

[464] 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

High Efficiency Gas Water Heater*

Unique Measure Code: RS_WT_TOS_GASDHW_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes the purchase of a high efficiency gas water heater meeting or exceeding ENERGY STAR criteria for the water heater category provided below, in place of a new unit rated at the minimum Federal Standard. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Definition of Baseline Condition

The baseline condition is a new conventional gas storage water heater rated at the federal minimum[465].

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

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

Definition of Efficient Condition

The efficient condition is a new high efficiency gas water heater meeting or exceeding the minimum efficiency Energy Star qualification criteria provided below[466]:

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[465] 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

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

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

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

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

Where:

EF_Baseline = Energy Factor rating for baseline equipment

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

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

EF_Efficient = Energy Factor Rating for efficient equipment

= Actual. If Tankless whole-house multiply rated efficiency by 0.91[467]. If unknown assume values in look up in table below

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[467] 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

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
= 45.5 gallons hot water per day per household/2.59 people per household[468]
= 17.6

Household = Average number of people per household

= *2.53* [469]

365.25 = Days per year, on average

γWater = Specific Weight of water
= 8.33 pounds per gallon

T_{out} = Tank temperature
= 125°F

T_{in} = Incoming water temperature from well or municipal system

= *60.9* [470]

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

---

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.

[468] Email message from Maureen Hodgins, Research Manager for Water Research Foundation, to TAC/SAG, August 26, 2014

[469] 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

[470] 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.

Illustrative example – do not use as default assumption
For example, installing a 40 gallon condensing gas storage water heater, with an energy factor of 0.82 in a single family house:

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

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost for this measure is dependent on the type of water heater as listed below471.

Water heater Type	Incremental Cost
Gas Storage	$400
Condensing gas storage	$685
Tankless whole-house unit	$605

Measure Life

The measure life is assumed to be 13 years[472].

Operation and Maintenance Impacts

n/a

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[471] 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)

[472] 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 standards[473]:

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

Definition of Efficient Condition

The efficient condition is a heat pump water heater.

Annual Energy Savings Algorithm

$$\Delta kWh = (((1/EF_{BASE} - 1/EF_{EFFICIENT}) * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) + kWh\_cooling - kWh\_heating$$

Where:

EF_{BASE} = Energy Factor (efficiency) of standard electric water heater according to federal standards[474]:

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[473] 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

[474] 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

*For <=55 gallons: 0.96 – (0.0003 * rated volume in gallons)*

*For >55 gallons: 2.057 – (0.00113 * rated volume in gallons)*

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

$EF_{EFFICIENT}$ *= Energy Factor (efficiency) of Heat Pump water heater*

= Actual. If unknown assume 2.0 [475]

GPD = Gallons Per Day of hot water use per person

= 45.5 gallons hot water per day per household/2.59 people per household[476]

= 17.6

Household = Average number of people per household

= 2.53 [477]

365.25 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

T_{OUT} *= Tank temperature*

= 125°F

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[475] 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

[476] Email message from Maureen Hodgins, Research Manager for Water Research Foundation, to TAC/SAG, August 26, 2014

[477] 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

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

= 60.9 [478]

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

3412 = *Conversion from Btu to kWh*

kWh_cooling[479] = *Cooling savings from conversion of heat in home to water heat*

$=(((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1/ EF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 33\%) / COP_{COOL}) * LM$

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[480]

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[478] 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.

[479] 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.

[480] 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).

COP_{COOL} = COP of central air conditioning

= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

LM = Latent multiplier to account for latent cooling demand

= 1.33 [481]

kWh_heating = *Heating cost from conversion of heat in home to water heat (dependent on heating fuel)*

For Natural Gas heating, kWh_heating = 0

For electric heating:

$= ((((GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412) - ((1/ EF_{NEW} * GPD * Household * 365.25 * \gamma Water * (T_{OUT} - T_{IN}) * 1.0) / 3412)) * LF * 49\%) / COP_{HEAT}$

Where:

47% = Portion of removed heat that results in increased heating load[482]

COP_{HEAT} = COP of electric heating system

= actual. If not available use[483]:

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[481] A sensible heat ratio (SHR) of 0.75 corresponds to a latent multiplier of 4/3 or 1.33. SHR of 0.75 for typical split system from page 10 of “Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers” by M. A. Andrade and C. W. Bullard, 1999: www.ideals.illinois.edu/bitstream/handle/2142/11894/TR151.pdf

[482] REMRate determined percentage (47%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

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

System Type	Age of Equipment	HSPF Estimate	COP_{HEAT} (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006 – 2014 (default)	7.7	2.26
	2015 on	8.2	2.40
Resistance	N/A	N/A	1.00

Prescriptive savings based on defaults provided above:

ΔkWH electric resistance heat = (((1/0.945 – 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) + kWh_cooling - kWh_heating

kWh_cooling = (((((17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) – ((1/ 2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412)) * 0.5 * 0.33) / 3.08) * 1.33

= 90.7 kWh

kWh_heating = ((((17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412) – ((1/ 2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412)) * 0.5 * 0.47) / 1.0

= 299.1 kWh

ΔkWH electric resistance heat = 1420.7 + 90.7 – 299.1
= 1212.3 kWh

ΔkWH heat pump heat = (((1/0.945 – 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) + kWh_cooling - kWh_heating

kWh_cooling = 90.7 kWh

kWh_heating = (((17.6 * 2.53 * 365.25 * 8.33 * (125-60.9) * 1.0) / 3412) - ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412)) * 0.5 * 0.47) / 2.0

= 149.5 kWh

ΔkWH heat pump heat = 1420.7 + 90.7 – 149.5
= 1361.9 kWh

ΔkWH fossil fuel heat = (((1/0.945 – 1/2.0) * 17.6 * 2.53 * 365.25 * 8.33 * (125 – 60.9) * 1.0) / 3412) + kWh_cooling - kWh_heating

kWh_cooling = 90.7

kWh_heating = 0

ΔkWH fossil fuel heat = 1420.7 + 90.7 - 0
= 1511.4 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.17 kW [484]

Annual Fossil Fuel Savings Algorithm

ΔMMBtu = - ((((GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412) – (((1/ EF_{NEW} * GPD * Household * 365.25 * γWater * (T_{OUT} – T_{IN}) * 1.0) / 3412))) * LF * 47% * 0.003412) / (ηHeat * % Natural Gas)

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[484] Based on a chart showing summer weekday average electrical demand on page 10 of FEMP Study “Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters” (http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf). Using data points from the chart, the average delta kW in heat pump mode during the peak hours compared to resistance mode is 0.17kW.

Where:

$\Delta MMBtu$ = Heating cost from conversion of heat in home to water heat for homes with Natural Gas heat.[485]

0.003412 = conversion factor (MMBtu per kWh)

$\eta Heat$ = Efficiency of heating system

= Actual.[486] *If not available use 72%.*[487]

% Natural Gas = Factor dependent on heating fuel:

Heating System	*%Natural Gas*
Electric resistance or heat pump	*0%*
Natural Gas	*100%*
Unknown heating fuel[488]	*62.5%*

Other factors as defined above

Prescriptive savings based on defaults provided above:

ΔMMBtu for fossil fuel heated homes:

$$\Delta MMBtu = - (((17.6 * 2.53 * 365.25 * 8.33 * (125-60.9) * 1.0) / 3412) - ((1/2.0 * 17.6 * 2.53 * 365.25 * 8.33 * (125 - 60.9) * 1.0) / 3412)) * 0.5 * 0.47 * 0.003412) / (0.72 * 1.0)$$

---

[485] This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater.

[486] Ideally, the System Efficiency should be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test. The Distribution Efficiency can be estimated via a visual inspection and by referring to a look up table such as that provided by the Building Performance Institute: (http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

[487] This has been estimated assuming typical efficiencies of existing heating systems weighted by percentage of homes with non-electric heating (based on Energy Information Administration, 2009 Residential Energy Consumption Survey: http://www.eia.gov/consumption/residential/data/2009/xls/HC6.9%20Space%20Heating%20in%20Midwest%20Region.xls).

[488] Based on KEMA baseline study for Maryland.

= - 1.41MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost for this measure is $1,000, for a HPWH with an energy factor of 2.0.[489]

Measure Life

The expected measure life is assumed to be 13 years.[490]

Operation and Maintenance Impacts

n/a

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[489] 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

[490] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Page 8-52 http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

Thermostatic Restrictor Shower Valve**

Unique Measure Code: RS_HV_TOS_GSHPS_0415
Effective Date: June 2015
End Date: TBD

Measure Description

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

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

Definition of Baseline Condition

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) * EPG_electric

Where:

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

DHW fuel	*%ElectricDHW*
Electric	*100%*
Natural Gas	*0%*
Unknown	*24%*[491]

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[491] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey

GPM_base_S = *Flow rate of the basecase showerhead, or actual if available*

Program	*GPM*
Direct-install, device only	*2.5* [492]
New Construction or direct install of device and low flow showerhead	*Rated or actual flow of program-installed showerhead*

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

= *0.89 minutes*[493]

Household = *Average number of people per household*

= *2.56* [494]

SPCD = *Showers Per Capita Per Day*

= *0.6*[495]

365.25 = *Days per year, on average.*

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

(RECS) 2009 for Mid Atlantic Region. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

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

[493] 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.

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

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

= 1.6 [496]

EPG_electric = Energy per gallon of hot water supplied by electric

*= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)*

*= (8.33 * 1.0 * (105 – 60.9)) / (0.98 * 3412)*

= 0.11kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water

= 105F [497]

SupplyTemp = Assumed temperature of water entering house

= 60.9 [498]

RE_electric = Recovery efficiency of electric water heater

= 98% [499]

3412 = Constant to convert Btu to kWh

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[496] 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" http://www.ebmud.com/sites/default/files/pdfs/market_penetration_study_0.pdf

[497] 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.

[498] 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.

[499] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

Illustrative Example - do not use as default assumption

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

$$\Delta kWh = 1.0 * (2.5 * 0.89 * 2.56 * 0.6 * 365.25 / 1.6) * 0.11$$

$$= 86 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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

$= ((GPM\_base\_S * L\_showerdevice) * Household * SPCD * 365.25 / SPH) * 0.746$[500] $/ GPH$

GPH = *Gallons per hour recovery of electric water heater calculated for 59.1 temp rise (120-60.9), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.*

$= 30.0$

Hours $= ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.746 / 30$

$= 19.4$ *hours*

CF = *Coincidence Factor for electric load reduction*

$= 0.0015$[501]

---

[500] 74.6% is the proportion of hot 120F water mixed with 60.1F supply water to give 105F shower water.

[501] Calculated as follows: Assume 11% showers take place during peak hours (based on: http://www.allianceforwaterefficiency.org/WorkArea/DownloadAsset.aspx?id=6020). 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

Illustrative example – do not use as default assumption

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

ΔkW = 86 / 19.4 * 0.0015

= 0.007 kW

Annual Fossil Fuel Savings Algorithm

ΔMMBtu = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas

Where:

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

DHW fuel	*%Fossil_DHW*
Electric	*0%*
Natural Gas	*100%*
Unknown	*76%*[502]

EPG_gas = Energy per gallon of Hot water supplied by gas

*= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 1,000,000)*

= 0.00065 MMBTu/gal

RE_gas = Recovery efficiency of gas water heater

= 75% For SF homes[503]

0.38/260 = 0.0015

[502] 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 geographical area then that should be used.

[503] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired

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:

ΔMMBTu = 1.0 * ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.00065
= 0.51 MMBtu

Water impact Descriptions and calculations

ΔCCF = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) / 748

Where:

748 = *Constant to convert from gallons to CCF*

Other variables as defined above

Illustrative example – do not use as default assumption

For example, a direct installed valve:

ΔCCF = ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) / 748
= 1.0 CCF

Measure Life

Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

The expected measure life is assumed to be 10 years. [504]

Deemed Measure Cost

The incremental cost of the measure should be the actual program cost or $30[505] if not available.

Operation and Maintenance Impacts

N/A

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

[505] 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_RTR_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:

ΔkWh[506] = (UA * (Tpre – Tpost) * Hours) / (3412 * RE_electric)

Where:

U =*Overall heat transfer coefficient of tank (BTU/hour-°F-ft^2)*

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

A = *Surface area of storage tank (square feet)*

---

[506] 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 = 24.99ft^2

Capacity (gal)	*A (ft^2)*[507]
30	*19.16*
40	*23.18*
50	*24.99*
80	*31.84*

Tpre = Actual hot water setpoint prior to adjustment.

= 135 degrees default

Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees

= 120 degrees default

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

= 8766

3412 = Conversion from Btu to kWh

RE_electric = Recovery efficiency of electric hot water heater

= 0.98 [508]

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[507] 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.

[508] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

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

$$\Delta kWh = (UA * (Tpre - Tpost) * Hours) / (3412 * RE\_electric)$$

$$= (((0.083 * 24.99) * (135 - 120) * 8766) / (3412 * 0.98)$$

$$= 81.6 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

Hours = *8766*

CF = *Summer Peak Coincidence Factor for measure*

= *1*

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

$$\Delta kW = (81.6/ 8766) * 1$$

$$= 0.00931 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

For homes with gas water heaters:

$$\Delta MMBtu = (UA * (Tpre - Tpost) * Hours) / (1{,}000{,}000 * RE\_gas)$$

Where

1,000,000 = *Converts Btus to MMbtu (btu/MMBtu)*

RE_gas = *Recovery efficiency of gas water heater*

= *0.75* [509]

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

$$\Delta MMBtu = (UA * (Tpre – Tpost) * Hours) / (RE\_gas)$$

$$= (((0.083 * 24.99) * (135 – 120) * 8766) / (1,000,000 * 0.75)$$

$$= 0.36 \text{ MMBtu}$$

Annual Water Savings Algorithm

N/A

Incremental Cost

The incremental cost of the setback 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

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[509] 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%.

Appliance End Use

Clothes Washer*

Unique Measure Code(s): RS_LA_TOS_CWASHES_0415, RS_LA_TOS_CWASHT2_0415, RS_LA_TOS_CWASHT3_0415, RS_LA_TOS_CWASHME_0415

Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding either the ENERGY STAR/CEE Tier 1, ENERGY STAR Most Efficient/CEE Tier 2 or CEE Tier 3 minimum qualifying efficiency standards presented below:

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR, CEE Tier 1	>= 2.38	>= 2.06	<= 3.7	<= 4.3
ENERGY STAR Most Efficient, CEE TIER 2	>= 2.74	>= 2.76	<= 3.2	<= 3.5
CEE TIER 3	>= 2.92	n/a	<= 3.2	n/a

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.

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

IMEF as of March 2015 is 1.84 for front loading units and 1.29 for top loading units.

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

(see '2015 Mid Atlantic CW Analysis.xls' for detailed calculation)

ΔkWh = [(Capacity * 1/IMEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer)] - [(Capacity * 1/IMEFeff * Ncycles) * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer)]

Where

Capacity = *Clothes Washer capacity (cubic feet)*
= *Actual. If capacity is unknown assume average 3.45 cubic feet*[510]

IMEFbase = *Integrated Modified Energy Factor of baseline unit*
= *Values provided in table below*

IMEFeff = *Integrated Modified Energy Factor of efficient unit*
= *Actual. If unknown assume average values provided below.*

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages[511]	
	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	>= 2.76	>= 2.74	98%	2%
CEE TIER 3	>= 2.92	n/a	>= 2.92	100%	0%

Ncycles = *Number of Cycles per year*

---

[510] 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.

[511] Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

= 254[512]

%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[513]		
	%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%
Unknown	65%[514]

%Electric_Dryer = Percentage of dryer savings assumed to be electric

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[512] 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.

[513] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and consumption data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm. See "2015 E$ Clothes Washer Analysis.xls" for the calculation.

[514] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%
Unknown	79%[515]

The prescriptive kWH savings based on values provided above where DHW and Dryer fuels are unknown is provided below[516]:

Efficiency Level	ΔkWH		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	112.7	84.2	102.2
ENERGY STAR Most Efficient, CEE TIER 2	145.0	162.2	145.4
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

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[515] 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.

[516] 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	Dryer/DHW Gas Combo	ΔkWH		
		Front	Top	Weighted Average
	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

ΔkW = ΔkWh/Hours * CF

Where:

Hours = Assumed Run hours of Clothes Washer
= 265 [517]
CF = Summer Peak Coincidence Factor for measure
= 0.029 [518]

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:

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[517] 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.

[518] Ibid.

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

$$\Delta\text{MMBtu} = [(\text{Capacity} * 1/\text{MEFbase} * \text{Ncycles}) * ((\%\text{DHWbase} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryerbase} * \%\text{Gas \_Dryer})] - [(\text{Capacity} * 1/\text{MEFeff} * \text{Ncycles}) * ((\%\text{DHWeff} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryereff} * \%\text{Gas\_Dryer})] * \text{MMBtu\_convert}$$

Where:

R_eff = *Recovery efficiency factor*
= *1.26*[519]

MMBtu _convert = *Convertion factor from kWh to MMBtu*
= *0.003413*

%Natural Gas_DHW = *Percentage of DHW savings assumed to be Natural Gas*

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[519] 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.

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%
Unknown	35%[520]

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	6%[521]

Other factors as defined above

The prescriptive MMBtu savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	ΔMMBtu		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	0.16	0.05	0.12
ENERGY STAR Most Efficient, CEE TIER 2	0.22	0.13	0.22
CEE TIER 3	0.22	n/a	0.22

The unit specific MMBtu savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Configuration	ΔMMBtu		
		Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	Electric Dryer/Electric DHW	0.00	0.00	0.00
	Electric Dryer/Gas DHW	0.43	0.11	0.32
	Gas Dryer/Electric DHW	0.20	0.19	0.20
	Gas Dryer/Gas DHW	0.63	0.30	0.51
	Electric Dryer/Electric DHW	0.00	0.00	0.00
	Electric Dryer/Gas DHW	0.58	0.31	0.57

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[520] 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.

[521] Default assumption for unknown is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

Efficiency Level	Configuration	ΔMMBtu		
		Front	Top	Weighted Average
ENERGY STAR Most Efficient, CEE TIER 2	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

$$\Delta \text{Water (CCF)} = (\text{Capacity} * (\text{IWFbase} - \text{IWFeff})) * \text{Ncycles}$$

Where

IWFbase = Integrated Water Factor of baseline clothes washer

= Values provided below

IWFeff = Integrated Water Factor of efficient clothes washer

= Actual. If unknown assume average values provided below.

Efficiency Level	IWF[522]		
	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	n/a	3.2

The prescriptive water savings for each efficiency level are presented below:

Efficiency Level	ΔWater (ccf per year)		
	Front Loading	Top Loading	Weighted Average
ENERGY STAR, CEE Tier 1	2.6	1.9	2.3

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[522] Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database accessed on 08/28/2014.

ENERGY STAR Most Efficient, CEE TIER 2	3.2	2.8	3.2
CEE TIER 3	3.2	6.9	3.2

kWh Savings from Water Reduction

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

ΔkWh_{water}[523] = 2.07 kWh * ΔWater (CCF)

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	ΔkWhwater		
	Front	Top	Weighted Average
ENERGY STAR, CEE Tier 1	5.4	3.9	4.8
ENERGY STAR Most Efficient, CEE TIER 2	6.6	5.9	6.6
CEE TIER 3	6.6	14.4	6.6

Incremental Cost

The incremental cost for this measure is provided in the table below[524]:

Efficiency Level	Market Opportunity Incremental Cost
ENERGY STAR, CEE Tier 1	$48
ENERGY STAR Most Efficient, CEE TIER 2	$269
CEE TIER 3	$297

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[523] 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.

[524] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See '2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls' for details..

Measure Life

The measure life is assumed to be 14 years [525].

Operation and Maintenance Impacts

n/a

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[525] 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_RTR_CWASHES_0415, RS_LA_ RTR_CWASHT2_0415, RS_LA_ RTR_CWASHT3_0415, RS_LA_ RTR_CWASHME_0415

Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the early removal of an existing inefficient clothes washer from service, prior to its natural end of life, and replacement with a new unit exceeding either the ENERGY STAR/CEE Tier 1, ENERGY STAR Most Efficient / CEE Tier 2 or CEE Tier 3 minimum qualifying efficiency standards presented below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)		Integrated Water Factor (IWF)	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR, CEE Tier 1	>= 2.38	>= 2.06	<= 3.7	<= 4.3
ENERGY STAR Most Efficient, CEE TIER 2	>= 2.74	>= 2.76	<= 3.2	<= 3.5
CEE TIER 3	>= 2.92	n/a	<= 3.2	n/a

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.

This is a retrofit measure.

Definition of Baseline Condition

The baseline condition is the existing inefficient clothes washer for the remaining assumed useful life of the unit, assumed to be 5 years[526], 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	1.84	1.29	4.7	8.4

Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the exceeding ENERGY STAR/ CEE Tier 1, ENERGY STAR Most Efficient / CEE Tier 2 or CEE Tier 3 standards as of 1/1/2015 as presented in the measure description.

Annual Energy Savings Algorithm

(see '2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls' for detailed calculation)

$$\Delta kWh = [(Capacity * 1/IMEFbase * Ncycles) * (\%CWbase + (\%DHWbase * \%Electric\_DHW) + (\%Dryerbase * \%Electric\_Dryer)] - [(Capacity * 1/IMEFeff * Ncycles) * (\%CWeff + (\%DHWeff * \%Electric\_DHW) + (\%Dryereff * \%Electric\_Dryer)]$$

Where

---

[526] Based on 1/3 of the measure life.

Capacity = Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume average 3.45 cubic feet[527]
IMEFbase = Integrated Modified Energy Factor of baseline unit
= Values provided in table below
IMEFeff = Integrated Modified Energy Factor of efficient unit
= Actual. If unknown assume average values provided below.

Efficiency Level	Integrated Modified Energy Factor (IMEF)			Weighting Percentages[528]	
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading
Existing Unit[529]	1.0	0.84	n/a[530]	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	>= 2.76	>= 2.74	98%	2%
CEE TIER 3	>= 2.92	n/a	>= 2.92	100%	0%

Ncycles = Number of Cycles per year
= 254[531]
%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)

---

[527] 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.

[528] Weighting percentages are based on available product from the CEC database.

[529] Existing units efficiencies are based upon an MEF of 1.26 , the 2004 Federal Standard, converted to IMEF using an ENERGY STAR conversion tool.

[530] For early replacement measures we will always know the configuration of the replaced machine.

[531] 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.

	Percentage of Total Energy Consumption[532]		
	%CW	%DHW	%Dryer
Federal Standard	8%	31%	61%
ENERGY STAR, CEE Tier 1	8%	23%	69%
ENERGY STAR Most Efficient, CEE TIER 2	14%	10%	76%
CEE TIER 3	14%	10%	77%

%Electric_DHW = *Percentage of DHW savings assumed to be electric*

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%

%Electric_Dryer = *Percentage of dryer savings assumed to be electric*

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Efficiency Level	Dryer/DHW Fuel Combo	Remaining life of existing unit (first 5 years) ΔkWH		Remaining measure life (next 9 years) ΔkWH	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top	Weighted 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

---

[532] 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.

	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

Summary Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Assumed Run hours of Clothes Washer*
= *265* [533]

CF = *Summer Peak Coincidence Factor for measure*
= *0.029* [534]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Efficiency Level	Dryer/DHW Fuel Combo	Remaining life of existing unit (first 5 years) ΔkW		Remaining measure life (next 9 years) ΔkW	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
		Front	Top	Weighted Average	Front	Top	Front	Top
ENERGY STAR, 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

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[533] 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.

[534] Ibid.

ENERGY STAR Most Efficient, CEE TIER 2	Electric Dryer/Electric DHW	0.061	0.079	0.023	37%	29%	0.041	0.050
	Electric Dryer/Fuel DHW	0.036	0.044	0.008	23%	19%	0.021	0.025
	Fuel Dryer/Electric DHW	0.028	0.038	0.014	51%	37%	0.021	0.026
	Fuel Dryer/Fuel DHW	0.003	0.004	0.000	-15%	-10%	0.001	0.001
CEE TIER 3	Electric Dryer/Electric DHW	0.063	0.081	0.025	40%	31%	0.043	0.052
	Electric Dryer/Fuel DHW	0.037	0.046	0.010	27%	22%	0.023	0.027
	Fuel Dryer/Electric DHW	0.028	0.039	0.015	52%	38%	0.022	0.026
	Fuel Dryer/Fuel DHW	0.003	0.004	0.000	-5%	-4%	0.001	0.002

Annual Fossil Fuel Savings Algorithm

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas DHW and Natural Gas dryer savings from total savings:

$$\Delta \text{MMBtu} = [(\text{Capacity} * 1/\text{IMEFbase} * \text{Ncycles}) * ((\%\text{DHWbase} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryerbase} * \%\text{Gas \_Dryer})] - [(\text{Capacity} * 1/\text{IMEFeff} * \text{Ncycles}) * ((\%\text{DHWeff} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryereff} * \%\text{Gas\_Dryer})] * \text{MMBtu\_convert}$$

Where:

R_eff = Recovery efficiency factor
= 1.26[535]
MMBtu _convert = Convertion factor from kWh to MMBtu
= 0.003413

%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas

DHW fuel	%Natural Gas_DHW
Electric	0%
Natural Gas	100%

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

---

[535] 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.

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

$$\Delta \text{Water (CCF)} = (\text{Capacity} * (\text{IWFbase} - \text{IWFeff})) * \text{Ncycles}$$

Where

WFbase = *Integrated Water Factor of baseline clothes washer*
= *Values provided below*
WFeff = *Integrated Water Factor of efficient clothes washer*
= *Actual. If unknown assume average values provided below.*

Efficiency Level	IWF[536]		
	Front Loading	Top Loading	Weighted Average
Existing[537]	8.2	8.4	n/a[538]
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	n/a	3.2

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below[539]:

Efficiency Level	Remaining life of existing unit (first 5 years) ΔWater (ccf per year)		Remaining measure life (next 9 years) ΔWater (ccf per year)	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
	Front	Top	Weighted Average	Front	Top	Front	Top
Existing	n/a	n/a	n/a	n/a	n/a	0.00	0.00
Federal Standard	n/a	n/a	n/a	n/a	n/a	0.00	0.00
ENERGY STAR, CEE Tier 1	5.0	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

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[536] Based on relevant specifications as of March 2015. Weighting percentages are based on available product from the CEC database.

[537] 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.

[538] For early replacement measures we will always know the configuration of the replaced machine.

[539] 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/AdvancedSearch.aspx)

CEE TIER 3	5.9	6.1	3.2	54%	52%	4.4	4.5

kWh Savings from Water Reduction

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

ΔkWh_{water}[540] $= 2.07\ kWh * \Delta Water\ (CCF)$

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	Remaining life of existing unit (first 5 years) ΔWater (ccf per year)		Remaining measure life (next 9 years) ΔWater (ccf per year)	Mid Life Adjustment		Equivalent Weighted Average Annual Savings	
	Front	Top	Weighted Average	Front	Top	Front	Top
Existing	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Federal Standard	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ENERGY STAR, CEE Tier 1	10.4	10.8	4.8	47%	44%	7.2	7.5
ENERGY STAR Most Efficient, CEE TIER 2	12.1	12.6	6.6	54%	52%	9.0	9.2
CEE TIER 3	12.1	12.6	6.6	54%	52%	9.0	9.2

Incremental Cost

The full measure cost assumption is provided below[541]:

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[540] 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.

[541] Based on weighted average of top loading and front loading units (based on available product from the CEC Appliance database) and cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool. See '2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls' for details.

Efficiency Level	Early Replacement Full Install Cost
ENERGY STAR, CEE Tier 1	$879
ENERGY STAR Most Efficient, CEE TIER 2	$1100
CEE TIER 3	$1128

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 3 years had the existing unit not been replaced is assumed to be $831.

Measure Life

The measure life is assumed to be 14 years [542] and the existing unit is assumed to have a remaining life of 5 years[543].

Operation and Maintenance Impacts

n/a

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[542] 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

[543] 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 3.0)[544] 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)[545]
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 effective 10/1/2012[546] as defined below:

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
<75	≥1.85
75 to ≤185	≥2.80

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[544] Energy Star Version 3.0 became effective 10/1/12

[545] 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

[546] http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/dehumid/ES_Dehumidifiers_Final_V3.0_Eligibility_Criteria.pdf?d70c-99b0

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

Annual Energy Savings Algorithm

$$\Delta kWh = (((Capacity * 0.473) / 24) * Hours) * (1 / (L/kWh\_Base) - 1 / (L/kWh\_Eff))$$

Where:

Capacity = Capacity of the unit (pints/day)
0.473 = Constant to convert Pints to Liters
24 = Constant to convert Liters/day to Liters/hour
Hours = Run hours per year
= 1632 [547]
L/kWh = 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	1.85	477	348	129
> 25 to ≤35	30	1.35	1.85	715	522	193
> 35 to ≤45	40	1.5	1.85	858	695	162
> 45 to ≤ 54	50	1.6	1.85	1005	869	136

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[547] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator http://www.myenergystar.com/Dehumidifiers.aspx

> 54 to ≤ 75	65	1.7	1.85	1230	1130	100
> 75 to ≤ 185	130	2.5	2.8	1673	1493	179
Average	46	1.51	1.85	983	800	183

Summary Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Annual operating hours*
= *1632 hours*[548]
CF = *Summer Peak Coincidence Factor for measure*
= *0.37* [549]

Capacity (pints/day) Range	ΔkW
≤25	0.029
> 25 to ≤35	0.044
> 35 to ≤45	0.037
> 45 to ≤ 54	0.031
> 54 to ≤ 75	0.023
> 75 to ≤ 185	0.041
Average	0.042

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

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[548] 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

[549] 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%

n/a

Incremental Cost

The assumed incremental capital cost for this measure is $45[550].

Measure Life

The measure life is assumed to be 12 years. [551]

Operation and Maintenance Impacts

n/a

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[550] 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

[551] ENERGY STAR Dehumidifier Calculator http://www.myenergystar.com/Dehumidifiers.aspx

ENERGY STAR Air Purifier/Cleaner

Unique Measure Code(s): RS_AP_TOS_AIRPUR_0414
Effective Date: June 2014
End Date: TBD

Measure Description

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of a baseline model.

Definition of Baseline Condition

The baseline equipment is assumed to be a conventional non-ENERGY STAR unit with consumption estimates based upon EPA research on available models, 2011[552].

Definition of Efficient Condition

The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below.

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[553] 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)

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[552] ENERGY STAR Appliance Savings Calculator; http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx

[553] Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard

Annual Energy Savings Algorithm

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

Where:

kWh_{BASE} = Baseline kWh consumption per year[554]

= see table below

kWh_{ESTAR} = ENERGY STAR kWh consumption per year[555]

= 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

Summary Coincident Peak kW Savings Algorithm

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

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[554] 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.

[555] Ibid.
Efficiency 3.0 CADR/Watt, 16 hours a day, 365 days a year and 0.6W standby power.

Hours = Average hours of use per year

= 5840 hours[556]

CF = Summer Peak Coincidence Factor for measure

= 0.67[557]

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 incremental cost for this measure is $0.[558]

Measure Life

The measure life is assumed to be 9 years[559].

Operation and Maintenance Impacts

There are no operation and maintenance cost adjustments for this measure.[560]

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[556] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

[557] Assumes appliance use is equally likely at any hour of the day or night.

[558] ENERGY STAR Appliance Savings Calculator; EPA research on available models, 2012

[559] ENERGY STAR Appliance Savings Calculator; Based on Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

[560] 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_DISHWAS_0415
Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR criteria. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[561]. 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

ΔkWh = (Load/CEFbase – Load/CEFeff) * Ncycles * %Electric

Where:

Load = *The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.*

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[561] ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

Dryer Size	Load (lbs.)[562]
Standard	8.45
Compact	3

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis[563]. If product class unknown, assume electric, standard.

Product Class	CEFbase (lbs/kWh)
Vented Electric, Standard (≥ 4.4 ft^3)	3.11
Vented Electric, Compact (120V) (< 4.4 ft^3)	3.01
Vented Electric, Compact (240V) (<4.4 ft^3)	2.73
Ventless Electric, Compact (240V) (<4.4 ft^3)	2.13
Vented Gas	2.84[564]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.[565] If product class unknown, assume electric, standard.

Product Class	CEFeff (lbs/kWh)
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	3.93
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	3.80
Vented Electric, Compact (240V) (< 4.4 ft^3)	3.45
Ventless Electric, Compact (240V) (< 4.4 ft^3)	2.68
Vented Gas	3.48[566]

Ncycles = Number of dryer cycles per year

= 311 cycles per year.[567]

%Electric = The percent of overall savings coming from

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[562] Based on ENERGY STAR test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[563] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

[564] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

[565] ENERGY STAR Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[566] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

[567] Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014.

electricity

Clothes Dryer Fuel Type	*%Electric* [568]
Electric	*100%*
Gas	*16%*

Product Class	Algorithm	ΔkWh
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	= ((8.45/3.11 – 8.45/3.93) * 311 * 100%)	176.3
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	= ((3/3.01 – 3/3.80) * 311 * 100%)	64.4
Vented Electric, Compact (240V) (< 4.4 ft^3)	= ((3/2.73 – 3/3.45) * 311 * 100%)	71.3
Ventless Electric, Compact (240V) (< 4.4 ft^3)	= ((3/2.13 – 3/2.68) * 311 * 100%)	89.9
Vented Gas	= ((8.45/2.84 – 8.45/3.48) * 311 * 16%)	27.2

Summary Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/Hours * CF

Where:

ΔkWh = *Energy Savings as calculated above*

Hours = *Annual run hours of clothes dryer.*

=290 hours per year.[569]

CF = *Summer Peak Coincidence Factor for measure*

= 2.9%[570]

Product Class	Algorithm	ΔkW
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	= 176.3/290 * 0.029	0.018
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	= 64.4/290 * 0.029	0.006
Vented Electric, Compact (240V) (< 4.4 ft^3)	= 71.3/290 * 0.029	0.007
Ventless Electric, Compact (240V) (< 4.4 ft^3)	= 89.9/290 * 0.029	0.009
Vented Gas	= 27.2/290 * 0.029	0.003

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[568] %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.

[569] Assumes average of 56 minutes per cycle based on Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014

[570] Consistent with coincidence factor of Clothes Washers; Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

Annual Fossil Fuel Savings Algorithm

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

ΔMMBtu = (Load/CEFbase – Load/CEFeff) * Ncycles * MMBtu_convert * %Gas

Where:

MMBtu_convert = Conversion factor from kWh to MMBtu

= 0.003413

%Gas = Percent of overall savings coming from gas

Clothes Dryer Fuel Type	*%Gas* [571]
Electric	*0%*
Gas	*84%*

Product Class	Algorithm	ΔMMBtu
Vented or Ventless Electric, Standard (≥ 4.4 ft^3)	n/a	0
Vented or Ventless Electric, Compact (120V) (< 4.4 ft^3)	n/a	0
Vented Electric, Compact (240V) (< 4.4 ft^3)	n/a	0
Ventless Electric, Compact (240V) (< 4.4 ft^3)	n/a	0
Vented Gas	=(8.45/2.84 – 8.45/3.48) * 311 * 0.003413 * 0.84	0.49

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152[572]

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[571] %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.

[572] Based on the difference in installed cost for an efficient dryer ($716) and standard dryer ($564). http://www.aceee.org/files/proceedings/2012/data/papers/0193-000286.pdf

Measure Life

The expected measure life is assumed to be 14 years[573].

Operation and Maintenance Impacts

n/a

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[573] 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.

The ENERGY STAR Dishwasher specification for Dishwashers is in the process of being revised from version 5.2 to version 6.0. The version 6.0 specification will become effective on January 29, 2016. Savings for both specification version 5.2 and 6.0 are contained in this measure characterization.

Definition of Baseline Condition

The baseline for this measure is defined as a new dishwasher that meets the Federal Standard efficiency standards as defined below[574]:

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 effective 01/20/2012[575] for version 5.2 and 01/29/2016[576] for version 6.0 as defined below:

ENERGY STAR	Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle

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[574] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

[575] http://www.energystar.gov/sites/default/files/specs//private/ENERGY%20STAR%20Version%205.2%20Residential%20Dishwasher%20Program%20Requirements.pdf

[576] http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206%200%20Final%20Draft%20Specification_Final.pdf

Version			
5.2	Standard	295	4.25
6.0	Standard	270	3.50

Annual Energy Savings Algorithm

ΔkWh[577] = ((kWh$_{Base}$ - kWh$_{ESTAR}$) * (%kWh_op + (%kWh_heat * %Electric_DHW)))

Where:

kWh$_{BASE}$ = *Baseline kWh consumption per year*

= *307 kWh*

kWh$_{ESTAR}$ = *ENERGY STAR kWh annual consumption*

ENERGY STAR Version	Maximum kWh/year
5.2	295
6.0	270

%kWh_op = *Percentage of dishwasher energy consumption used for unit operation*

= *1 - 56%*[578]

= *44%*

%kWh_heat = *Percentage of dishwasher energy consumption used for water heating*

= *56%*[579]

%Electric_DHW = *Percentage of DHW savings assumed to be electric*

---

[577] 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.

[578] ENERGY STAR Dishwasher Calculator, see ‘EnergyStarCalculatorConsumerDishwasher.xls’.

[579] Ibid.

DHW fuel	*%Electric_DHW*
Electric	*100%*
Natural Gas	*0%*
Unknown	*65%*[580]

ENERGY STAR Specification	DHW Fuel	Algorithm	ΔkWh
5.2	Electric	=((307 - 295) * (0.44 + (0.56 * 1.0)))	12.0
5.2	Unknown	= ((307 - 295) * (0.44 + (0.56 * 0.65)))	9.6
6.0	Electric	= ((307 - 270) * (0.44 + (0.56 * 1.0)))	37
6.0	Unknown	= ((307 - 270) * (0.44 + (0.56 * 0.65)))	29.7

Summary Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Annual operating hours*[581]

= *210 hours*

CF = *Summer Peak Coincidence Factor*

= *2.6%* [582]

ENERGY STAR Specification	DHW Fuel	Algorithm	ΔkW
5.2	Electric	= 12/210 * 0.026	0.0015

---

[580] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the Mid-Atlantic region.

[581] 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://www.eia.gov/consumption/residential/

[582] 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.

5.2	Unknown	= 9.65/210 * 0.026	0.0012
6.0	Electric	= 37/210 * 0.026	0.0046
6.0	Unknown	= 29.75/210 * 0.02	0.0037

Annual Fossil Fuel Savings Algorithm

ΔMMBtu = (kWh_{Base} - kWh_{ESTAR}) * %kWh_heat * %Natural Gas_DHW * R_eff * 0.003413

Where

%kWh_heat = *% of dishwasher energy used for water heating*

= *56%*

%Natural Gas_DHW = *Percentage of DHW savings assumed to be Natural Gas*

DHW fuel	*%Natural Gas_DHW*
Electric	*0%*
Natural Gas	*100%*
Unknown	*35%*[583]

R_eff = *Recovery efficiency factor*

= *1.26*[584]

0.003413 = *factor to convert from kWh to MMBtu*

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[583] 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 geographical area then that should be used.

[584] 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.

ENERGY STAR Specification	DHW Fuel	Algorithm	ΔMMBtu
5.2	Gas	= (307 - 295) * 0.56 * 1.0 * 1.26 * 0.003413	0.03
5.2	Unknown	= (307 - 295) * 0.56 * 0.35 * 1.26 * 0.003413	0.01
6.0	Gas	= (307 - 270) * 0.56 * 1.0 * 1.26 * 0.003413	0.09
6.0	Unknown	= (307 - 270) * 0.56 * 0.35 * 1.26 * 0.003413	0.03

Annual Water Savings Algorithm

ΔCCF = ($Water_{Base}$ - $Water_{EFF}$) * GalToCCF

Where

$Water_{Base}$ = *water consumption of conventional unit*

= *700 gallons*[585]

$Water_{EFF}$ = *annual water consumption of efficient unit:*

ENERGY STAR Specification	WaterEFF (gallons)
5.2	595[586]
6.0	490[587]

GalToCCF = factor to convert from gallons to CCF

= 0.001336

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[585] 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/

[586] Assuming 4.25 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/

[587] Assuming 3.50 gallons/cycle (maximum allowed) and 140 cycles per year based on a weighted average of dishwasher usage in the Mid-Atlantic Region derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

ENERGY STAR Specification	Algorithm	ΔCCF
5.2	= (700 – 595) * 0.001336	0.14
6.0	= (700 – 490) * 0.001336	0.28

Incremental Cost

The assumed incremental capital cost for this measure is \$50[588].

Measure Life

The measure life is assumed to be 10 years[589].

Operation and Maintenance Impacts

n/a

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[588] Estimate based on review of Energy Star stakeholder documents

[589] ENERGY STAR Dishwasher Calculator, see 'EnergyStarCalculatorConsumerDishwasher.xls'.

Shell Savings End Use

Air sealing

Unique Measure Code: RS_SL_RTR_AIRSLG_0711
Effective Date: June 2014
End Date: TBD

Measure Description

This measure characterization provides a method of claiming both heating and cooling (where appropriate) savings from the improvement of a residential building's air-barrier, which together with its insulation defines the thermal boundary of the conditioned space.

The measure assumes that a trained auditor, contractor or utility staff member is on location, and will measure and record the existing and post air-leakage rate using a blower door in accordance with industry best practices[590]. 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

Cooling savings from reduction in Air Conditioning Load:

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[590] See BPI Building Analyst and Envelope Professional standards, http://www.bpi.org/standards_approved.aspx

$$\Delta kWh = [(((CFM50Exist - CFM50New) / N\text{-}factor) * 60 * CDH * DUA * 0.018) / 1{,}000 / \eta Cool] * LM$$

Where:

CFM50exist = *Blower Door result (CFM_{50}) prior to air sealing*
= *actual*

CFMnew = *Blower Door result (CFM_{50}) after air sealing*
= *actual*

N-factor = *conversion from CFM_{50} to $CFM_{Natural}$*[591]
= *dependent on exposure level:*

Exposure	*Well Shielded*	*24*
	Normal	*20*
	Exposed	*18*

CDH = *Cooling Degree Hours*[592]
= *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*[593]
= *0.75*

0.018 = *The volumetric heat capacity of air (Btu/ft3°F)*

ηCool = *Efficiency in SEER of Air Conditioning equipment*

---

[591] 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

[592] 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)

[593] 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.

= actual. If not available use[594]:

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

LM *= Latent Multiplier*
= 6.9[595]

Illustrative example – do not use as default assumption
A well shielded home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

ΔkWh = [(((3,400 – 2,250) / 24) *60 * 7,514 * 0.75 * 0.018) / 1,000 / 12] * 6.9

= 168 kWh

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

ΔkWh = ((((CFM50Exist – CFM50New) / N-factor) * 60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat) * 293.1

Where:

N-factor *= conversion from CFM_{50} to $CFM_{Natural}$[596]*
= Based on building height and exposure level:

# Stories:	1	1.5	2	3

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[594] 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.

[595] The Latent Multiplier is used to convert the Sensible cooling savings calculated to a value representing Sensible and Latent Cooling loads. The value 6.9 is derived from Harriman et al "Dehumidification and Cooling Loads From Ventilation Air", ASHRAE Journal, which provides a Latent to Sensible load ratio for Baltimore, MD of 4.7:0.8. Thus, the total load (i.e. sensible + latent) to sensible load ratio is 5.5 to 0.8, or 6.9 to 1. While this report also provides a value for Wilmington, DE (7.14), because it is very similar and within the likely range of error for this algorithm, and because there is no equivalent value for Washington DC, for simplicity sake we recommend using a single value to account for the latent cooling loads throughout the region.

[596] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location, height of building (stack effect) and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122

Exposure	Well Shielded	24	21.6	19.2	16.8
	Normal	20	18	16	14
	Exposed	18	16.2	14.4	12.6

HDD = *Heating Degree Days*
= *dependent on location*[597]

Location	*Heating Degree Days (60˚F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[598]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*[599]
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 well shielded 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.

ΔkWh = [(((3,400 – 2,250) / 24) *60 * 24 * 3,275 * 0.018) / 1,000,000 / 2.5] * 293.1

477 kWh

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[597] 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.

[598] 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.

[599] To convert HSPF to COP, divide the HSPF rating by 3.413.

Summary Coincident Peak kW Savings Algorithm

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

Where:

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	FLHcool
Wilmington, DE	*524* [600]
Baltimore, MD	*542* [601]
Washington, DC	*681*

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

= *0.69* [602]

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

= *0.66* [603]

Illustrative example – do not use as default assumption
A well shielded 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.

$$\Delta kW = 168 / 524 * 0.69$$

$$= 0.22 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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[600] 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)

[601] 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.

[602] 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.

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

For homes with Fossil Fuel Heating:

$$\Delta MMBTU = (((CFM50Exist - CFM50New) / N\text{-}factor) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$$

Where:

N-factor = *conversion from* CFM_{50} *to* $CFM_{Natural}$[604]

= *Based on building height and exposure level:*

	# Stories:	1	1.5	2	3
Exposure	Well Shielded	24	21.6	19.2	16.8
	Normal	20	18	16	14
	Exposed	18	16.2	14.4	12.6

HDD = *Heating Degree Days*

= *dependent on location*[605]

Location	***Heating Degree Days (60°F set point)***
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

ηHeat = *Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*

= *actual*[606]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[607]*.*

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[604] N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location, height of building (stack effect) and exposure of the home to wind, based on methodology developed by Lawrence Berkeley Laboratory (LBL). http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940111.html#94011122

[605] 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.

[606] 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.

[607] 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

Illustrative example – do not use as default assumption
A well shielded home in Wilmington, DE with a 70% heating system efficiency, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta MMBtu = (((3{,}400 - 2{,}250) / 24) *60 * 24 * 3{,}275 * 0.018) / 1{,}000{,}000 / 0.7$$

$$= 5.8 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual installation and labor cost to perform the air sealing work.

Measure Life

The measure life is assumed to be 15 yrs[608].

Operation and Maintenance Impacts

n/a

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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.

[608] 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

Attic/ceiling/roof insulation

Unique Measure Code: RS_SL_RTR_ATTICI_0711
Effective Date: June 2014
End Date: TBD

Measure Description

This measure characterization is for the installation of new insulation in the attic/roof/ceiling of a residential building. The measure assumes that an auditor, contractor or utility staff member is on location, and will measure and record the existing and new insulation depth and type (to calculate R-values), the surface area of insulation added, and where possible the efficiency of the heating and cooling system used in the home.

This is a retrofit measure.

Definition of Baseline Condition

The existing insulation R-value should include the total attic floor / roof assembly. An R-value of 5 should be assumed for the roof assembly plus the R-value of any existing insulation[609]. 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:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * CDH * DUA * Area) / 1{,}000 / \eta Cool$$

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[609] The R-5 assumption for roof assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; “BESTEST-EX Interim Test Procedure” p27. The attic floor and roof should be modeled as a system including solar gains and attic ventilation, and R-5 is the standard assumption for the thermal resistance of the whole attic/roof system.

Where:

Rexist = R-value of roof assembly plus any existing insulation
= actual (minimum of R-5)
Rnew = R-value of roof assembly plus new insulation
= actual
CDH = Cooling Degree Hours[610]
= 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[611]
= 0.75
Area = square footage of area covered by new insulation
= actual
ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available use[612]*:*

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

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.

$$\Delta kWh = ((1/5 - 1/30) * 9{,}616 * 0.75 * 1{,}200) / 1{,}000 / 12$$

$$= 120kWh$$

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[610] Derived by summing the delta between the average outdoor temperature and the base set point of 75 degrees (above which cooling is assumed to be used), each hour of the year. Hourly temperature data obtained from TMY3 data (http://rredc.nrel.gov/solar/)

[611] 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.

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

Savings for homes with electric heat (Heat Pump of resistance):

$$\Delta kWh = (((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1,000,000 / \eta Heat) * 293.1$$

HDD = *Heating Degree Days*
= *dependent on location*[613]

Location	*Heating Degree Days (60˚F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

1,000,000 = Converts Btu to MMBtu
ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[614]*:*

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

Illustrative example – do not use as default assumption
Insulating 1200 square feet of attic from R-5 to R-30 in a home with a 2.5COP Heat Pump in Baltimore, MD.

$$\Delta kWh = (((1/5 - 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 2.5) * 293.1$$

$$= 1,945 \text{ kWh}$$

---

[613] 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.

[614] 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.

Summer Coincident Peak kW Savings Algorithm

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

Where:

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	FLHcool
Wilmington, DE	*524* [615]
Baltimore, MD	*542* [616]
Washington, DC	*681*

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

= *0.69* [617]

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

= *0.66* [618]

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.

$$\Delta kW = 120 / 542 * 0.69$$

$$= 0.15 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

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[615] 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)

[616] 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.

[617] 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.

[618] 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.

ΔMMBTU = ((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat

Where:

HDD = *Heating Degree Days*
= *dependent on location*[619]

Location	*Heating Degree Days (60˚F set point)*
Wilmington, DE	*3,275*
Baltimore, MD	*3,457*
Washington, DC	*2,957*

ηHeat = *Efficiency of Heating equipment (equipment efficiency * distribution efficiency)*
= *actual*[620]. *If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[621].

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.

ΔMMBtu =((1/5 – 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 0.75

= 22 MMBtu

---

[619] 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.

[620] 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.

[621] 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.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual installation and labor cost to perform the insulation work.

Measure Life

The measure life is assumed to be 25 years[622].

Operation and Maintenance Impacts

n/a

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[622] 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

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 [623]

Heating kWh Savings (Electric Resistance) = 356 kWh per 100 square feet window area

Heating kWh Savings (Heat Pump COP 2.0) = 194 kWh per 100 square feet window area

Cooling kWh Savings (SEER 10) = 205 kWh per 100 square feet window area

Summer Coincident Peak kW Savings Algorithm

$$\Delta kWcooling = \Delta kWREM * CF$$

---

[623] 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:

ΔkWREM = Delta kW calculated in REMRate model
= 0.12 kW per 100 square feet window area

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69 [624]

CF_{PJM} = PJM Summer Peak Coincidence Factor for Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather
= 0.66 [625]

ΔkW_{SSP} cooling = 0.12 * 0.69

= 0.083 kW per 100 square feet of windows

ΔkW_{PJM} cooling = 0.12 * 0.66

= 0.079 kW per 100 square feet of windows

Annual Fossil Fuel Savings Algorithm

n/a for homes with electric heat.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $150 per 100 square feet of windows.[626]

Measure Life

The measure life is assumed to be 25 years.[627]

Operation and Maintenance Impacts

n/a

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[624] 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.

[625] 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.

[626] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007.

[627] 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

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

$$\Delta kWh = kWh_{Base} - kWh_{Two\ Speed}$$[628]

Where:

kWh_{Base} = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= *707 kWh*

$kWh_{Two\ Speed}$ = *typical consumption for an efficient two speed pump motor*
= *177 kWh*

$$\Delta kWh = 707 - 177$$

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[628] 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

= 530 kWh

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$ [629]

Where:

kW_{Base} = *Connected load of baseline motor*
= *1.3 kW*
$kW_{Two\ Speed}$ = *Connected load of two speed motor*
= *0.171 kW*
CF_{SSP} = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*
= *0.20*[630]
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*[631]

$\Delta kW_{SSP} = (1.3\text{-}0.171) * 0.20$

= 0.23 kW

$\Delta kW_{SSP} = (1.3\text{-}0.171) * 0.27$

= 0.31 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[629] 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

[630] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[631] Ibid.

The incremental cost for this measure is assumed to be $175 for a two speed pool pump motor[632].

Measure Life

The measure life is assumed to be 10 yrs[633].

Operation and Maintenance Impacts

n/a

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[632] Based on review of Lockheed Martin pump retail price data, July 2009.

[633] 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 two speed pump operating at 40% speed (50% flow) for 13 hours per day.

Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}$$ [634]

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*

$$\Delta kWh = 707 - 113$$

---

[634] 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

$= 594$ kWh

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [635]

Where:

kW_{Base} = *Connected load of baseline motor*
= *1.3 kW*
$kW_{Two\ Speed}$ = *Connected load of two speed motor*
= *0.087 kW*
CF_{SSP} = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*
= *0.20*[636]
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*[637]

$$\Delta kW_{SSP} = (1.3-0.087) * 0.20$$

$$= 0.24 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3-0.\ 087) * 0.27$$

$$= 0.34 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[635] 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

[636] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[637] Ibid.

The incremental cost for this measure is assumed to be $750 for a variable speed pool pump motor[638].

Measure Life

The measure life is assumed to be 10 yrs[639].

Operation and Maintenance Impacts

n/a

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[638] Based on review of Lockheed Martin pump retail price data, July 2009.

[639] VEIC estimate.

Plug Load End Use

Advanced Power Strip

Unique Measure Code: RS_PL_TOS_APS_0711
Effective Date: June 2014
End Date: TBD

Measure Description

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

This measure characterization provides a single prescriptive savings assumption based on office and entertainment savings from a 2011 NYSERDA Advanced Power Strip Research Report and weightings and in service rates based on EmPower evaluations.

Definition of Baseline Condition

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

Definition of Efficient Condition

The efficient case is the use of a Current-Sensing Master/Controlled Advanced Power Strip.

Annual Energy Savings Algorithm

$$\Delta kWh = (kWh_{office} * Weighting_{Office} + kWh_{Ent} * Weighting_{Ent}) * ISR$$

Where:

kWh_{office} = Estimated energy savings from using an APS in a home office

= 31.0 kWh[640]

$Weighting_{Office}$ = Relative penetration of computers

= 41%[641]

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system

= 75.1 kWh[642]

$Weighting_{Ent}$ = Relative penetration of televisions

= 59%[643]

ISR = In service rate

= 83.2%[644]

$$\Delta kWh = (31 * 41\% + 75.1 * 59\%) * 83.2$$

$$= 47.4 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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[640] NYSERDA 2011, Advanced Power Strip Research Report, http://www.nyserda.ny.gov/-/media/Files/EERP/Residential/Energy-Efficient-and-ENERGY-STAR-Products/Power-Management-Research-Report.pdf. Note that estimates are not based on pre/post metering but on analysis based on frequency and consumption of likely products in active, standby and off modes. This measure should be reviewed frequently to ensure that assumptions continue to be appropriate.

[641] EmPower 2012 Residential Retrofit evaluation

[642] NYSERDA 2011, Advanced Power Strip Research Report

[643] EmPower 2012 Residential Retrofit evaluation

[644] EmPower 2013 Residential Retrofit evaluation of the Quick Home Energy Check-up program

Hours = *Annual hours when controlled standby loads are turned off*
= *6,351*[645]

CF = *Coincidence Factor*
= *0.8*[646]

$$\Delta kW = (47.4/6{,}351) * 0.8$$
$$= 0.0060\ kW$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $35[647].

Measure Life

The measure life is assumed to be 4 years[648].

Operation and Maintenance Impacts

n/a

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[645] EmPower 2012 Residential Retrofit evaluation

[646] Ibid

[647] NYSERDA 2011, Advanced Power Strip Research Report

[648] 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.

COMMERCIAL & INDUSTRIAL MARKET SECTOR

Lighting End Use

General Purpose CFL Screw base, Retail – Commercial*

Unique Measure Code(s): CI_LT_TOS_CFLSCR_0615
Effective Date: June 2015
End Date: TBD

Measure Description

This measure characterizes the installation of a general purpose compact fluorescent light bulb (CFL) in place of an incandescent bulb. The measure provides assumptions based on the use of a program that uses a Time of Sale implementation strategy. Direct Install assumptions are presented with the residential characterization. This characterization is for a general purpose screw based CFL bulb (A-lamps), and not a specialty bulb (e.g., reflector (PAR) lamp, globes, candelabras, 3-ways, etc.).

Definition of Baseline Condition

The baseline is the installation of a halogen incandescent light bulb meeting the standards described in the Energy Independence and Security Act of 2007.[649]

Definition of Efficient Condition

The efficient condition is the installation of a compact fluorescent light bulb.

Annual Energy Savings Algorithm

ΔkWh = ((WattsBASE - WattsEE) /1000) * HOURS * ISR * WHFe

Where:

WattsBASE = *Based on lumens of CFL bulb*[650]:

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

[650] Base wattage is based upon the post first phase of EISA wattage and wattage bins consistent with ENERGY STAR, v1.1;

Minimum Lumens	Maximum Lumens	WattsBASE
4,000	6,000	300
3,001	3,999	200
2,550	3,000	150
2,000	2,549	125
1,600	1,999	72
1,100	1,599	53
800	1,099	43
450	799	29
250	449	25

WattsEE = *Actual wattage of CFL purchased / installed*

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.*[651]

ISR = *In Service Rate or percentage of units rebated that are installed and operational*

= *1.00* [652]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Illustrative examples – do not use as default assumption

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http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

[651] 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.

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

For example, a 19W, 1,200 lumen CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory:

ΔkWh = ((53 - 19) / 1000) * 2,969 * 1.00 * 1.10

= 111 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((WattsBASE - WattsEE) / 1000) * ISR * WHFd * CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. Otherwise, see table “Waste Heat Factors for C&I Lighting – Unknown HVAC Types” in Appendix D.

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 19W, 1,200 lumen CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory and estimating PJM summer peak coincidence:

ΔkW = ((53 - 19) / 1000) * 1.00 * 1.32 * 0.69

= 0.03 kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75
= (-ΔkWh / WHFe) * 0.00073

Where:

0.7 = *Aspect ratio* [653]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [654]
0.75 = *Assumed heating system efficiency* [655]

Illustrative examples – do not use as default assumption

For example, assuming a 19W CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory:

ΔMMBTU = (-111 / 1.10) * 0.00073

= -0.07 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

For the Retail (Time of Sale) measure, the incremental capital cost is $1.80.[656]

Measure Life

The measure life by building type is presented in the table below.[657]

Building Type	Measure Life (Years)
Grocery	1.4
Health	2.6

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[653] 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.

[654] 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).

[655] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[656] Based on incremental costs for 60W equivalent (dominant bulb) from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.

[657] Measure life calculated by building type as “10,000/HOURS” where 10,000 is the median lifetime of General Purpose Replacement, CFL-type ENERGY STAR Certified Light Bulbs (“ENERGY STAR Certified Light Bulbs,” Accessed on April 13, 2015, <http://www.energystar.gov/productfinder/product/certified-light-bulbs/results>

Building Type	Measure Life (Years)
Office	3.4
Other	2.2
Retail	2.0
School	3.9
Warehouse/ Industrial	2.4
Unknown	2.6

Operation and Maintenance Impacts

For convenience, the levelized baseline replacement cost over the lifetime of the CFL is presented below (see MidAtlantic Lighting Adjustments and O&M_042015.xls). The key assumptions used in this calculation are documented below:

Attribute	Halogen Incandescent
Replacement Lamp Cost	$1.40[658]
Replacement Labor Cost	$1.54[659]
Component Life (Hours)	1,000[660]

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below[661]:

Building Type	NPV of Baseline Replacement Costs
Grocery	$26.18

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[658] Based on for 60W EISA equivalent (dominant bulb) from "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014.

[659] Itron, Inc. 2014. A Study of Non-Energy Impacts for the State of Maryland REVIEW DRAFT.

[660] The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, Optimal Energy and confirmed by N. Horowitz at NRDC), so the lifetime of these EISA qualified bulbs is assumed to be 1,000 hours.

[661] Note, these values have been adjusted by the appropriate In Service Rate (1.00). See 'MidAtlantic Lighting Adjustments and O&M_042015.xls' for more information. The discount rate used for these calculations is 5.0%.

Building Type	NPV of Baseline Replacement Costs
Health	$25.35
Office	$24.82
Other	$25.76
Retail	$25.76
School	$24.69
Warehouse/ Industrial	$25.63
Unknown	$25.35

High Performance and Reduced Wattage T8 Lighting Equipment*

Unique Measure Code(s): CI_LT_TOS_HPT8_0614 and CI_LT_RTR_HPT8_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure promotes the installation of High-Performance T8 (HPT8) or Reduced Wattage (RWT8) 4-ft lamp/ballast systems that have higher lumens per watt than standard 4-ft T8 systems. This results in lamp/ballast systems that produce equal or greater lumens than standard T8 systems, while using fewer watts. The Consortium for Energy Efficiency (CEE) maintains specifications and a list for qualifying High Performance and Reduced Wattage 4-ftT8 lamps and ballasts. The list is updated frequently and is available at http://library.cee1.org/content/commercial-lighting-qualifying-products-lists.

In November 2014, federal minimum standards for ballasts increased to meet CEE performance levels for HPT8 systems. In response, in January 2015, CEE published an updated Commercial Lighting Systems Initiative that transitioned the T8 specification to solely a replacement lamp strategy.[662] This new strategy is not technology dependent; both conventional fluorescent lamps and LED replacement lamps may qualify under the new requirements. CEE no longer maintains a list of ballasts that meet the previous HPT8 ballast specifications; however, an archived list of qualifying ballasts can be viewed at the aforementioned website. As a result, measure savings should no longer be claimed for more efficient ballasts for time of sale applications.

For time of sale or new construction, this measure assumes that a HPT8 or RWT8 fixture is installed instead of a 4-ft T8 fixture meeting federal minimum standards for lamp and ballast performance. For retrofit situations, it is assumed that the lamp(s) and ballast(s) in an existing 4-ft T12 fixture are replaced with qualifying HPT8 or RWT8 components.

Definition of Baseline Condition

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[662] Consortium for Energy Efficiency. Janurary 2015. CEE Commercial Lighting Initiative Specification for T8 Replacement Lamps. <http://library.cee1.org/sites/default/files/library/12035/CEE_T8_Replacement_Lamp_Spec_Jan2015_Updated03242015.pdf>

The baseline condition is assumed to be the existing lighting fixture in retrofit applications. For time of sale or new construction applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. number of lamps), federal minimum standards, and applicable building energy codes. For illustrative purposes the following baseline conditions are assumed:

Illustrative examples – do not use as default assumption

Time of Sale or New Construction: a 3-lamp standard performance 4-ft F32 T8 fixture with normal output electronic ballast with an input wattage of 89W.

Retrofit: a 3-lamp 4-ft F34 T12 fixture with magnetic ballast with an input wattage of 136W.

Definition of Efficient Condition

The efficient conditions for the time of sale and retrofit applications are a qualifying High Performance or Reduced Watt T8 fixture and lamp/ballast combination, respectively. For illustrative purposes the following high efficiency conditions for the corresponding baselines are assumed:

Illustrative examples – do not use as default assumption

Time of Sale or New Construction: a 3-lamp CEE High Performance T8 fixture with electronic, normal output type ballast with a fixture input wattage of 72W.

Retrofit: relamp / reballast with qualifying lamps and ballast with resulting fixture input wattage of 72W.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = Connected load of baseline fixture (for "Time of Sale" measures)
Or = Connected load of existing fixture (for "Retrofit" measures)
WattsEE = Connected load of HPT8 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.[663]

ISR *= In Service Rate or percentage of units rebated that get installed*
= 1.00 [664]

WHFe *= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

Illustrative examples – do not use as default assumption

For example, assuming installation in a conditoned office building with gas heat in BGE service territory in 2014:

Time of Sale or New Construction:

$$\Delta kWh = ((89 - 72) / 1000) * 2,969 * 1.00 * 1.10$$

$$= 56 \text{ kWh per fixture}$$

Retrofit:

$$\Delta kWh = ((136 - 72) / 1000) * 2,969 * 1.00 * 1.10$$

$$= 209 \text{ kWh per fixture}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE – WattsEE) / 1000) * ISR * WHFd * CF$$

Where:

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[663] 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.

[664] 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.

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

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 installation in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

Time of Sale or New Construction:

ΔkW = ((89 - 72) / 1000) * 1.00 * 1.32 * 0.69

= 0.015 kW per fixture

Retrofit:

ΔkW = ((136 - 72) / 1000) * 1.00 * 1.32 * 0.69

= 0.058 kW per fixture

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75

= -ΔkWh * 0.00065

Where:

0.7 = *Aspect ratio* [665]

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[665] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating*[666]
0.75 = *Assumed heating system efficiency*[667]

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs will vary by specific equipment installed. The incremental costs for the example measures are assumed to be $25 for time of sale or new construction and $60 for retrofit.[668]

Measure Life

The measure life is assumed to be 15 years for “Time of Sale” or “New Construction” measures. For “Retrofit” measure lifetimes by year, see the table below.[669]

Measure Life for Retrofit Measures with T12 Baseline

Year	2015	2016	2017
Measure Life	4.6	4.3	No T12 baseline

On June 26, 2009, the U.S. Department of Energy issued a final rule establishing new energy conservation standards for general service fluorescent lamps. These standards cover the most common types of linear fluorescent lamps including all 4-foot T12 and T8 lamps. Beginning July 14, 2012, the manufacture of T12 linear fluorescent lamps and the lowest efficiency 700-series T8 lamps was largely banned; however, 800-series standard T8 lamps will be unaffected. Some manufacturers will continue to produce an exempted type of T12 lamp with greater than 87 CRI. However, this lamp will be several times the cost of banned T12 lamps and will drive more users to upgrade to T8 systems.

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[666] 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).
[667] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.
[668] Efficiency Vermont Technical Reference Manual 201409-85b55, DecembeMayr 201408.
[669] 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.

If a customer relamped an existing fixture with T12s the day the standard took effect, an assumption can be made that they would likely need to upgrade to, at a minimum, 800-series T8s in less than 6 years' time. This assumes the T12s installed have a typical rated life of 20,000 hours and are operated for 3,500 hours annually. Certainly, it is not realistic that everyone would wait until the final moment to relamp with T12s. Also, the exempted T12 lamps greater than 87 CRI will continue to be available to purchase, albeit at much higher cost. Therefore the more likely scenario would be a gradual shift to T8s over the 6 year timeframe. To simplify this assumption, it is recommended that the assumed measure life be gradually reduced between 2012 and 2017 as presented in the table above. *Note: Adjusted measures lives take into account the savings that would result over the duration of the unadjusted measure life relative to new baseline T8 fixtures once T12s are no longer available.*

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of replacement lamps and ballasts between the efficient and baseline cases, there are significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs will vary by specific equipment installed/replaced. For the selected examples presented in the "Definition of Baseline Condition" and "Definition of Efficient Condition" sections:[670]

Illustrative examples – do not use as default assumption

Retrofit[671]

	Baseline Linear Fluorescent (Standard T8)		Efficient Linear Fluorescent (High Performance T8)	
	Lamp (each)	Ballast	Lamp (each)	Ballast
Replacement Cost	$5.17	$35	$7.67	$47.50

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[670] Unless otherwise noted, all table values adapted from Efficiency Vermont Technical Reference Manual 2013-82.5, August 2013.

[671] While the retrofit example assumes a baseline T12 system for calculating the first year annual savings, the baseline component values for the retrofit scenario reflect a standard T8 system because it is assumed that standard T12 components will no longer be sold in 2017 (when T12 lamps installed in 2012 are expected to fail assuming 3,500 annual operating hours and 20,000 lamp life) when relamping/reballasting is necessary due to federal standards.

Component Life[672] (years)	5.71[673]	20[674]	8.57[675]	20[676]

Time of Sale or New Construction

	Baseline Linear Fluorescent (Standard T8)		Efficient Linear Fluorescent (High Performance T8)	
	Lamp (each)	**Ballast**	**Lamp (each)**	**Ballast**
Replacement Cost	$5.17	$47.50	$7.67	$47.50
Component Life[677] (years)	5.71[678]	20[679]	8.57[680]	20[681]

The calculated net present value of the net replacement costs by market are presented below[682]:

Application	NPV of Net Replacement Costs
	2015
Retrofit	$52.08
Time of Sale or New Construction	$5.65

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[672] Based on lamp life divided by / assumed annual operatingrun hours.
[673] Assumes baseline lamp with rated life of 20,000 hours operated for 3,500 hours annually.
[674] Assumes baseline ballast with rated life of 70,000 hours operated for 3,500 hours annually.
[675] Assumes efficient lamp with rated life of 30,000 hours operated for 3,500 hours annually.
[676] Assumes efficient ballast with rated life of 70,000 hours operated for 3,500 hours annually.
[677] Based on lamp life divided by/ assumed annual operating hours.
[678] Assumes baseline lamp with rated life of 20,000 hours operated for 3,500 hours annually.
[679] Assumes baseline ballast with rated life of 70,000 hours operated for 3,500 hours annually.
[680] Assumes efficient lamp with rated life of 30,000 hours operated for 3,500 hours annually.
[681] Assumes efficient ballast with rated life of 70,000 hours operated for 3,500 hours annually.
[682] Note, these values have been adjusted by the appropriate In Service Rate (1.0) and assume a 5% discount rate. Additionally, the retrofit example assumes the ballast must be replaced at the time the existing T12 lamps failfter 40,000 hours. See “MidAtlantic Lighting Adjustments and O&M_042015.xls” for calculations.

T5 Lighting

Unique Measure Code(s): CI_LT_TOS_T5_0614 and CI_LT_RTR_T5_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure describes the installation of high-bay T5 lamp/ballast systems.

Definition of Baseline Condition

The baseline condition is a metal-halide fixture.

Definition of Efficient Condition

The efficient condition is a four Lamp T5 High Output fixture.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = *Actual Connected load of baseline fixture*
WattsEE = *Actual Connected load of T5 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.*[683]
ISR = *In Service Rate or percentage of units rebated that get installed*
= *1.00* [684]

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[683] 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.

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

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Illustrative examples – do not use as default assumption

For example, a 240W T5 fixture installed in place of a 455W metal-halide in a conditoned warehouse with gas heat in BGE service territory in 2014:

$$\Delta kWh = ((455 - 240) / 1000) * 4,116 * 1.00 * 1.02$$

$$= 902.6 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

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 240W T5 fixture installed in place of a 455W metal-halide in a warehouse and estimating PJM summer peak coincidence:

$$\Delta kW = ((455 - 240) / 1000) * 1.00 * 1.24 * 0.72$$

$$= 0.19 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75
= -ΔkWh * 0.00065

Where:

0.7 = Aspect ratio [685]
0.003413 = Constant to convert kWh to MMBTU
0.23 = Fraction of lighting heat that contributes to space heating [686]
0.75 = Assumed heating system efficiency [687]

Illustrative examples – do not use as default assumption

For example, a 240W T5 fixture installed in place of a 455W metal-halide in a conditoned warehouse with gas heat in 2014:

ΔMMBTU = -902.6 * 0.00065

= -0.59 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $300.[688]

Measure Life

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[685] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[686] 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).

[687] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[688] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

The measure life is assumed to be 15 years.[689]

Operation and Maintenance Impacts

n/a

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[689] '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

LED Exit Sign

Unique Measure Code(s): CI_LT_RTR_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 retrofit installations.

Definition of Baseline Condition

The baseline condition is an exit sign with a non-LED light-source.

Definition of Efficient Condition

The efficient condition is an exit sign illuminated with light emitting diodes (LED).

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = *Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.*[690]

WattsEE = *Actual Connected load of LED exit sign*

HOURS = *Average hours of use per year*

= *8,760* [691]

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

= *1.00* [692]

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[690] Assumes a fluorescent illuminated exit sign. Wattage consistent with ENERGY STAR assumptions. See http://www.energystar.gov/ia/business/small_business/led_exitsigns_techsheet.pdf.

[691] Assumes operation 24 hours per day, 365 days per year.

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

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Illustrative examples – do not use as default assumption

For example a 5W LED lamp in place of a 16W CFL in a conditoned office building with gas heat in BGE service territory in 2014:

$$\Delta kWh = ((16 - 5) / 1000) * 8,760 * 1.00 * 1.10$$

$$= 106.0 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

CF = *Summer Peak Coincidence Factor for measure*
= *1.0* [693]

Illustrative examples – do not use as default assumption

For example, a 5W LED lamp in place of a 16W CFL installed in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = ((16 - 5) / 1000) * 1.00 * 1.32 * 1.0$$

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[693] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

$= 0.015$ kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00065$$

Where:

0.7 = *Aspect ratio* [694]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [695]

0.75 = *Assumed heating system efficiency* [696]

Illustrative examples – do not use as default assumption

For example, a 5W LED lamp in place of a 16W CFL installed in a conditoned office building with gas heat in BGE service territory in 2014:

$$\Delta MMBTU = -106 * 0.00065$$

$$= -0.069 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $35.[697]

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[694] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[695] 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).

[696] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[697] Represents the full installed cost of an LED exit sign. LED exit signs can typically be purchased for ~$25 (http://www.exitlightco.com/category/Exit-Signs.html and http://www.simplyexitsigns.com). Assuming replacing exit sign requires 15 minutes of a

Measure Life

The measure life is assumed to be 7 years.[698]

Operation and Maintenance Impacts

	Baseline
	CFL
Replacement Cost	$12[699]
Component Life (years)	1.14[700]

The calculated net present value of the baseline replacement costs are presented below[701]:

	NPV of Baseline Replacement Costs
Baseline	2014
CFL	$62.59

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common building laborer's time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately $35.

[698] 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. Measure life in source study is reduced by ~50% assuming existing equipment is at one half of its useful life.

[699] 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. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately $12.

[700] 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.

[701] Note, these values have been adjusted by the appropriate In Service Rate.

Solid State Lighting (LED) Recessed Downlight Luminaire*

Unique Measure Code: CI_LT_TOS_SSLDWN_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 Specification for Solid State Luminaires[702]. 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. They currently are *not* subject to EISA regulations and so this characterization does not include the baseline shift provided in other lighting measures.

Definition of Baseline Condition

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1{,}000) * ISR * HOURS * WHFe$$

Where:

WattsBASE = *Connected load of baseline lamp*

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[702] ENERGY STAR specification can be viewed here: http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/SSL_FinalCriteria.pdf

= Actual if retrofit, if LED lumens is known - find the equivalent baseline wattage from the table below[703], if unknown assume 65W[704]

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Reflector with medium screw bases w/ diameter <=2.25"	400	449	40
	450	499	45
	500	649	50
	650	1199	65
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)	640	739	40
	740	849	45
	850	1179	50
	1180	1419	65
	1420	1789	75
	1790	2049	90
	2050	2579	100
	2580	3429	120
	3430	4270	150
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26'' and ≤ 2.5" (*see exceptions below)	540	629	40
	630	719	45
	720	999	50
	1000	1199	65
	1200	1519	75
	1520	1729	90
	1730	2189	100
	2190	2899	120
	2900	3850	150
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649-1179[705]	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40

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

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

[705] The upper bounds for these categories depends on the lower bound of the next higher wattage, which varies by bulb type.

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	450	719	45
*All reflector lamps below lumen ranges specified above	200	299	20
	300	399-639[706]	30

WattsEE = *Connected load of efficient lamp*
= *Actual. If unknown assume12W* [707]
ISR = *In Service Rate or percentage of units rebated that get installed.*
= *1.0*[708]
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.*[709]
WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Summary Coincident Peak kW Savings Algorithm

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

Where:

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[706] As above.

[707] Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc. (https://www2.buildinggreen.com/article/led-downlight-llf-most-efficient-market)

[708] 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.

[709] 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.

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

CF = *Summer Peak Coincidence Factor for measure*
= *See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.*

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$

$$= (-\Delta kWh / WFHe) * 0.00073$$

Where:

0.7 = *Aspect ratio* [710]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [711]

0.75 = *Assumed heating system efficiency* [712]

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 incremental cost for this measure is assumed to be $36[713].

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[710] 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.

[711] 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).

[712] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[713] Based on VEIC product review, April 2015. Baseline bulbs available in $3-$5 range, and SSL bulbs available in $20-$60 range. Incremental cost of $36 therefore assumed ($4 for the baseline bulb and $40 for the SSL). Note, this product is likely to fall rapidly in cost, so this

Measure Life

The measure life is assumed to be 10 years[714].

Operation and Maintenance Impacts

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

	BR-type Incandescent
Replacement Lamp Cost	$4.00
Replacement Labor Cost	$2.56[715]
Component Life (years)	0.57[716]

The calculated net present value of the baseline replacement costs is $89.49.[717]

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should be reviewed frequently. Product review, November 2012 and March 2014 suggests incremental cost estimate is still appropriate and wide range of costs available.

[714] The ENERGY STAR specification for solid state recessed downlights requires luminaires to maintain >=70% initial light output for 35,000 hours in a commercial application. Measure life is therefore assumed to be 10 years (calculated as 35,000 hours divided by an approximate 3,500 annual operating hours).

[715] Itron, Inc. 2014. A Study of Non-Energy Impacts for the State of Maryland REVIEW DRAFT.

[716] 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.

[717] 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. For illustrative purposes, a baseline three lamp 4ft T8 Fixture with input wattage of 89W is assumed.

Definition of Efficient Condition

The efficient condition will vary depending on the existing fixture and the number of lamps removed. For illustrative purposes, a two lamp 4ft T8 Fixture on a three lamp ballast (67W) is assumed.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * WHFe$$

Where:

WattsBASE = Actual Connected load of baseline fixture
WattsEE = Actual Connected load of delamped fixture
HOURS = Average hours of use per year
= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.[718]
WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.

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[718] 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.

= 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. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((WattsBASE - WattsEE) /1000) * WHFd * CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

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, one lamp of a three lamp 4ft T8 Fixture (89W) is removed (leaving 67W) in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

ΔkW = ((89 - 67) / 1000) * 1.32 * 0.69

= 0.020 kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75
= -ΔkWh * 0.00065

Where:

0.7 = *Aspect ratio* [719]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [720]
0.75 = *Assumed heating system efficiency* [721]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $10.8 per fixture.[722]

Measure Life

The measure life is assumed to be 15 years.[723]

Operation and Maintenance Impacts

Delamping reduces the number of periodic lamp replacements required, saving $1.25/year.

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[719] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[720] 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).

[721] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[722] Assumes delamping a single fixture requires 15 minutes of a common building laborer's time in Washington D.C.; Adapted from RSMeans Electrical Cost Data 2008.

[723] 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

Occupancy Sensor – Wall-, Fixture-, or Remote-Mounted

Unique Measure Code(s): CI_LT_TOS_OSWALL_0614, CI_LT_TOS_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

$$\Delta kWh = kWconnected * HOURS * SVGe * ISR * WHFe$$

Where:

kWconnected= Assumed kW lighting load connected to control.

HOURS = Average hours of use per year

= If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D. Otherwise, use site specific annual operating hours information.[724]

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[724] 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.

SVGe = *Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
= 0.28 [725]

ISR = *In Service Rate or percentage of units rebated that get installed*
= 1.00 [726]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

Summer Coincident Peak kW Savings Algorithm

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

Where:

SVGd = *Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.*
= 0.14 [727]

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

CF = *Summer Peak Coincidence Factor for measure*
= See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.

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[725] 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.

[726] 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.

[727] 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.

Illustrative examples – do not use as default assumption

For example, a 400W connected load being controlled in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 * 0.14 * 1.00 * 1.32 * 0.69$$

$$= 0.051 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00065$$

Where:

0.7 = *Aspect ratio* [728]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [729]

0.75 = *Assumed heating system efficiency* [730]

Annual Water Savings Algorithm

n/a

Incremental Cost

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[728] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[729] 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).

[730] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

The incremental cost for this measure is assumed to be $115 per control for wall occupancy sensors, $200 per control for fixture-mounted and remote-mounted occupancy sensors.[731]

Measure Life

The measure life is assumed to be 10 years.[732]

Operation and Maintenance Impacts

n/a

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[731] Northeast Energy Efficiency Partnerships Incremental Cost Study Report, Navigant, 2011. Sensors costs assume the simple average of cost for those sensors using only passive infrared technology and those using both passive infrared and ultrasonic technology.

[732] 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
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

$$\Delta kWh = kWconnected \times HOURS \times SVG \times ISR \times WHFe$$

Where:

kWconnected= Assumed kW lighting load connected to control.
HOURS = Average hours of use per year
= If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D. Otherwise, use site specific annual operating hours information.[733]
SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.

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[733] 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.

= 0.28 [734]

ISR = *In Service Rate or percentage of units rebated that get installed*
= 1.00 [735]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

Summary Coincident Peak kW Savings Algorithm[736]

$$\Delta kW = kWconnected \times SVG \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.

CF = *Summer Peak Coincidence Factor for measure*
= See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.

Illustrative examples – do not use as default assumption

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[734] 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.

[735] 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.

[736] 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.

For example, a 400W connected load being controlled in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 * 0.28 * 1.00 * 1.32 * 0.69$$

$$= 0.10 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00065$$

Where:

0.7 = *Aspect ratio* [737]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [738]
0.75 = *Assumed heating system efficiency* [739]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $100 per ballast controlled for both fixture-mounted and remote-mounted daylight sensors.[740]

Measure Life

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[737] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[738] 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).

[739] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[740] 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.

The measure life is assumed to be 10 years.[741]

Operation and Maintenance Impacts

n/a

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

Advanced Lighting Design – Commercial*

Unique Measure Code(s): CI_LT_TOS_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.[742]

Definition of Efficient Condition

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[742] Energy code lighting power density requirements can generally be satisfied by using one of two methods. The Building Area Method simply applies a blanket LPD requirement to the entire building based on the building type. Broadly speaking, as long as the total connected lighting wattage divided by the total floor space does not exceed the LPD requirement, the code is satisfied. The second method, the Space-by-Space Method, provides LPD requirements by space type based on the function of the particular space (e.g., “Hospital – Operating Room”, “Library – Reading Room”). LPD requirements must be satisfied for each individual space in the building. This method usually allows a higher total connected wattage as compared to the Building Area Method.

The efficient condition assumes lighting systems that achieve lighting power densities below the maximum lighting power densities required by the relevant jurisdictional energy codes as described above. Actual lighting power densities should be determined on a site-specific basis.

Annual Energy Savings Algorithm[743]

$$\Delta kWh = ((LPDBASE - LPDEE) / 1000) * AREA * HOURS * WHFe$$

Where:

LPDBASE = *Baseline lighting power density for building or space type (W/ft^2). See tables below for values by jurisdiction and method.*

LPDEE = *Efficient lighting power density (W/ft^2)*
= *Actual calculated*

AREA = *Building or space area (ft^2)*

HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D. Otherwise, use site specific annual operating hours information.*[744]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Building Area Method Baseline LPD Requirements by Jurisdiction[745]

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[743] 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.

[744] 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.

[745] IECC 2015, Table C405.4.2(1); IECC 2012, Table C405.5.2(1). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2010, Table 9.5.1. As the IECC 2012 requirements are less stringent they are presented here.

	Lighting Power Density (W/ft^2)	
Building Area Type	**Washington, D.C. and Delaware**	**Maryland**
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
Police Station	1.00	0.87
Post Office	1.10	0.87
Religious Building	1.30	1.00
Retail	1.40	1.26

	Lighting Power Density (W/ft^2)	
Building Area Type	Washington, D.C. and Delaware	Maryland
School/University	1.20	0.87
Sports Arena	1.10	0.91
Town Hall	1.10	0.89
Transportation	1.00	0.70
Warehouse	0.60	0.66
Workshop	1.40	1.19

Space-by-Space Method Baseline LPD Requirements for Washington, D.C. and Delaware[746]

Common Space-By-Space Types	Lighting Power Density (W/ft^2)
Atrium - First 40 feet in height	0.03 per ft. ht.
Atrium - Above 40 feet in height	0.02 per ft. ht.
Audience/seating area - Permanent	
For auditorium	0.9
For performing arts theater	2.6
For motion picture theater	1.2
Classroom/lecture/training	1.3
Conference/meeting/multipurpose	1.2
Corridor/transition	0.7
Dining Area	
Bar/lounge/leisure dining	1.4
Family dining area	1.4
Dressing/fitting room performing arts theater	1.1

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[746] 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.

Electrical/mechanical	1.1
Food preparation	1.2
Laboratory for classrooms	1.3
Laboratory for medical/industrial/research	1.8
Lobby	1.1
Lobby for performing arts theater	3.3
Lobby for motion picture theater	1.0
Locker room	0.8
Lounge recreation	0.8
Office – enclosed	1.1
Office - open plan	1.0
Restroom	1.0
Sales area	1.6
Stairway	0.7
Storage	0.8
Workshop	1.6
Courthouse/police station/penitentiary	
Courtroom	1.9
Confinement cells	1.1
Judge chambers	1.3
Penitentiary audience seating	0.5
Penitentiary classroom	1.3
Penitentiary dining	1.1
Building Specific Space-By-Space Types	**Lighting Power Density (W/ft^2)**
Automobile – service/repair	0.7
Bank/office - banking activity area	1.5
Dormitory living quarters	1.1
Gymnasium/fitness center	

Fitness area	0.9
Gymnasium audience/seating	0.4
Playing area	1.4
Healthcare clinic/hospital	
Corridor/transition	1.0
Exam/treatment	1.7
Emergency	2.7
Public and staff lounge	0.8
Medical supplies	1.4
Nursery	0.9
Nurse station	1.0
Physical therapy	0.9
Patient Room	0.7
Pharmacy	1.2
Radiology/imaging	1.3
Operating room	2.2
Recovery	1.2
Lounge/recreation	0.8
Laundry - washing	0.6
Hotel	
Dining area	1.3
Guest rooms	1.1
Hotel lobby	2.1
Highway lodging dining	1.2
Highway lodging guest rooms	1.1
Library	
Stacks	1.7
Card file and cataloging	1.1
Reading area	1.2

Manufacturing	
Corridor/transition	0.4
Detailed manufacturing	1.3
Equipment room	1.0
Extra high bay (>50-foot floor-ceiling height)	1.1
High bay (25-50-foot floor-ceiling height)	1.2
Low bay (<25-foot floor-ceiling height)	1.2
Museum	
General exhibition	1.0
Restoration	1.7
Parking garage – garage areas	0.2
Convention center	
Exhibit space	1.5
Audience/seating area	0.9
Fire stations	
Engine room	0.8
Sleeping quarters	0.3
Post office – sorting area	0.9
Religious building	
Fellowship hall	0.6
Audience seating	2.4
Worship pulpit/choir	2.4
Retail	
Dressing/fitting area	0.9
Mall concourse	1.6
Sales area	1.6
Sports arena	
Audience seating	0.4
Court sports area - Class 4	0.7

Court sports area - Class 3	1.2
Court sports area - Class 2	1.9
Court sports area - Class 1	3.0
Ring sports arena	2.7
Transportation	
Airport/train/bus baggage area	1.0
Airport concourse	0.6
Terminal - ticket counter	1.5
Warehouse	
Fine material storage	1.4
Medium/bulky material	0.6

Space-by-Space Method Baseline LPD Requirements for Maryland[747]

Common Space-By-Space Types	Lighting Power Density (W/ft^2)
Atrium	
Less than 40 feet in height	0.03 per foot in total height
Greater than 40 feet in height	0.40 + 0.02 per foot in total height
Audience seating area	
In an auditorium	0.63
In a convention center	0.82
In a gymnasium	0.65
In a motion picture theater	1.14
In a penitentiary	0.28
In a performing arts theater	2.43
In a religious building	1.53
In a sports arena	0.43
Otherwise	0.43

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[747] IECC 2015, Table C405.4.2(2).

Banking activity area	1.01
Breakroom (See Lounge/Breakroom)	
Classroom/lecture hall/training room	
In a penitentiary	1.34
Otherwise	1.24
Conference/meeting/multipurpose room	1.23
Copy/print room	0.72
Corridor	
In a facility for the visually impaired (and not used primarily by staff)	0.92
In a hospital	0.79
In a manufacturing facility	0.41
Otherwise	0.66
Courtroom	1.72
Computer room	1.71
Dining area	
In a penitentiary	0.96
In a facility for the visually impaired (and not used primarily by staff)	1.9
In bar/lounge or leisure dining	1.07
In cafeteria or fast food dining	0.65
In family dining	0.89
Otherwise	0.65
Electrical/mechanical room	0.95
Emergency vehicle garage	0.56
Food preparation area	1.21
Guest room	0.47
Laboratory	
In or as a classroom	1.43
Otherwise	1.81
Laundry/washing area	0.6

Loading dock, interior	0.47
Lobby	
In a facility for the visually impaired (and not used primarily by the staff)	1.8
For an elevator	0.64
In a hotel	1.06
In a motion picture theater	0.59
In a performing arts theater	2.0
Otherwise	0.9
Locker room	0.75
Lounge/breakroom	
In a healthcare facility	0.92
Otherwise	0.73
Office	
Enclosed	1.11
Open plan	0.98
Parking area, interior	0.19
Pharmacy area	1.68
Restroom	
In a facility for the visually impaired (and not used primarily by the staff)	1.21
Otherwise	0.98
Sales area	1.59
Seating area, general	0.54
Stairway (See space containing stairway)	
Stairwell	0.69
Storage room	0.63
Vehicular maintenance area	0.67
Workshop	1.59
Building Type Specific Space Types	**Lighting Power Density (W/ft^2)**

Facility for the visually impaired	
In a chapel (and not used primarily by the staff)	2.21
In a recreation room (and not used primarily by the staff)	2.41
Automotive (See Vehicular Maintenance Area above)	
Convention Center – exhibit space	1.45
Dormitory – living quarters	0.38
Fire Station – sleeping quarters	0.22
Gymnasium/fitness center	
In an exercise area	0.72
In a playing area	1.2
Healthcare facility	
In an exam/treatment room	1.66
In an imaging room	1.51
In a medical supply room	0.74
In a nursery	0.88
In a nurse’s station	0.71
In an operating room	2.48
In a patient room	0.62
In a physical therapy room	0.91
In a recovery room	1.15
Library	
In a reading area	1.06
In the stacks	1.71
Manufacturing facility	
In a detailed manufacturing facility	1.29
In an equipment room	0.74
In an extra high bay area (greater than 50’ floor-to-ceiling height)	1.05
In a high bay area (25’-50’ floor-to-ceiling height)	1.23

In a low bay area (less than 25' floor-to-ceiling height)	1.19
Museum	
In a general exhibition area	1.05
In a restoration room	1.02
Performing arts theater – dressing room	0.61
Post Office – Sorting Area	0.94
Religious buildings	
In a fellowship hall	0.64
In a worship/pulpit/choir area	1.53
Retail facilities	
In a dressing/fitting room	0.71
In a mall concourse	1.1
Sports arena – playing area	
For a Class I facility	3.68
For a Class II facility	2.4
For a Class III facility	1.8
For a Class IV facility	1.2
Transportation facility	
In a baggage/carousel area	0.53
In an airport concourse	0.36
At a terminal ticket counter	0.8
Warehouse – storage area	
For medium to bulky, palletized items	0.58
For smaller, hand-carried items	0.95

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft^2 conditoned office building with gas heat in in DE using the Building Area Method with an LPDEE of 0.75:

$$\Delta kWh = ((0.9 - 0.75) / 1000) * 15{,}000 * 2{,}969 * 1.10$$

$$= 7{,}348 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((LPDBASE – LPDEE) / 1000) * AREA * WHFd * CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

CF = *Summer Peak Coincidence Factor for measure*
= *See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.*

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft^2 conditoned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75 and estimating PJM summer peak coincidence:

$$\Delta kWh = ((0.9 - 0.75) / 1000) * 15{,}000 * 1.32 * 0.69$$

$$= 2.05 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

Where:

0.7 = *Aspect ratio* [748]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [749]
0.75 = *Assumed heating system efficiency* [750]

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft^2 conditoned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75:

$$\Delta kWh = (-7{,}348\ /\ 1.10) * 0.00073$$

$$= -4.88\ MMBtu$$

Annual Water Savings Algorithm

n/a

Incremental Cost

Incremental costs will vary greatly from project to project depending on the advanced lighting design principles and lighting technologies used. Incremental costs should be estimated on a case-by-case basis.

Measure Life

The measure life is assumed to be 15 years.[751]

Operation and Maintenance Impacts

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[748] 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.

[749] 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).

[750] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[751] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf. Assumes Advanced Lighting Design lifetime will be consistent with that of the "Fluorescent Fixture" measure from the reference document. This measure life assumes that the most common implementation of this measure will be for new construction or major renovation scenarios where new fixtures are installed. In such cases, adopting the fixture lifetime for the LPD reduction measure seems most appropriate.

Due to differences in costs and lifetimes of the efficient and baseline replacement components, there may be significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs should be estimated on a case-by-case basis.

LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Luminaires and Retrofit Kits*

Unique Measure Code(s): CI_LT_TOS_LEDODPO_0615 and CI_LT_RTR_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 List[752].

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

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[752] DesignLights Consortium Qualified Products List <https://www.designlights.org/QPL>

= *If the actual LED fixture wattage is unknown, use the default values presented in the "Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage" table below based on the appropriate baseline description.*

Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage[753]

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

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[753] 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.

Measure Category	Baseline Description	WattsBASE	Efficient Description	WattsEE
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*
= *If annual operating hours are unknown, assume 3,338* [754]. *Otherwise, use site specific annual operating hours information.*[755]

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

ΔkWh = ((288 – 172) / 1000) * 3,338

= 387 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((WattsBASE - WattsEE) / 1000) * CF

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0* [756]

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

ΔkW = ((288 - 172) / 1000) * 0

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[754] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[755] 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.

[756] It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

= 0 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[757]

Measure Category	Installed Cost	Incremental Cost
LED Outdoor Pole/Arm Area and Roadway Luminaires		
Fixture replacing up to 175W HID	$460	$195
Fixture replacing 176-250W HID	$620	$310
Fixture replacing 251+ HID	$850	$520
LED Wall-Mounted Area Luminaires		
All Fixtures	$250	$120

Measure Life

The measure life is assumed to be 18 years.[758]

Operation and Maintenance Impacts[759]

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. Estimated O&M savings and the component cost and lifetime assumptions are presented in the table below.

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[757] Efficiency Maine Technical Reference User Manual No.2010-1, 2010.

[758] 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.

[759] 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 Category	Baseline Description	Lamp Life (Hours)	Lamp Cost	Lamp Rep. Labor/Disposal Cost	Ballast Life (Hours)	Ballast Cost	Ballast Rep. Labor/Disposal Cost	NPV O&M Savings
LED Outdoor Area Fixture replacing up to 175W HID	175W or less base HID	10000	$31.00	$2.92	40000	$95.85	$27.50	$180.37
LED Outdoor Area Fixture replacing 176-250W HID	176W up to 250W base HID	10000	$21.00	$2.92	40000	$87.75	$27.50	$147.44
LED Outdoor Area Fixture replacing 251-400W HID	251W up to 400W base HID	10000	$11.00	$2.92	40000	$60.46	$27.50	$114.52
LED Outdoor Area Fixture replacing 401-1000W HID	401W up to 1000W base HID	10000	$23.00	$2.92	40000	$100.09	$27.50	$154.03

LED High-Bay Luminaires and Retrofit Kits*

Unique Measure Code(s): CI_LT_TOS_LEDHB_0615 and CI_LT_RTR_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 List[760].

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = Actual Connected load of baseline fixture
WattsEE = Actual Connected load of the LED fixture
HOURS = Average hours of use per year

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[760] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

= *If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D. Otherwise, use site specific annual operating hours information.*[761]

ISR = *In Service Rate or percentage of units rebated that get installed*
= *1.00* [762]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Illustrative examples – do not use as default assumption

For example, a 250W pulse start metal halide fixture delivering 16,000 mean system lumens is replaced with an LED fixture drawing 178W in a warehouse with gas heat in BGE service territory:[763]

$$\Delta kWh = ((288 - 178) / 1000) * 4{,}116 * 1.00 * 1.02$$

$$= 462 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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[761] 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.

[762] 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.

[763] Wattage of illustrative LED luminaire developed by averaging the wattage for all DesignLights Consortium qualified high-bay products from the DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL> delivering between 90% and 100% of the baseline mean system lumens.

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*
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 250W metal halide fixture delivering 16,000 mean system lumens is replaced with an LED fixture drawing 178W in a warehouse with gas heat in BGE service territory and estimating PJM summer peak coincidence:

$$\Delta kW = ((288 - 178) / 1000) * 1.00 * 1.24 * 0.72$$

$$= 0.10 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00065$$

Where:
0.7 = *Aspect ratio* [764]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [765]
0.75 = *Assumed heating system efficiency* [766]

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[764] 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.

[765] 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).

[766] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

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.

Illustrative examples – do not use as default assumption

For the illustrative example, the incremental cost is approximately $200.[767]

Measure Life

The measure life is assumed to be 12 years for both luminaires and retrofit kits.[768]

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. Estimated O&M savings should be calculated on a site-specific basis depending on the actual baseline and efficient equipment.

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[767] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013.

[768] 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.

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
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 kits for general area illumination in place of a fluorescent light source. These luminaires and retrofit kits are typically recessed, suspended, or surface-mounted and intended to provide ambient lighting in settings such as office spaces, schools, retail stores, and other commercial environments. Eligible applications include time of sale or new construction and retrofits applications. Because of the improved optical control afforded by LED luminaires and retrofit kits, LED lighting systems can typically reduce total lumen output while maintaining required illuminance on work surfaces. Therefore, illuminance calculations should be performed in the process of selecting LED luminaires and retrofit kits.

Definition of Baseline Condition

The baseline condition is defined as a 1x4, 2x2, or 2x4 fixture with a fluorescent light-source. Typical baseline technologies include fluorescent T8 fixtures. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. number of lamps).

Definition of Efficient Condition

The efficient condition is defined as an LED high-bay luminaire. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List[769].

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = Actual Connected load of baseline fixture

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[769] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

WattsEE	*= Actual Connected load of the LED fixture*
HOURS	*= Average hours of use per year* *= If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D.*[770] *Otherwise, use site specific annual operating hours information.*[771]
ISR	*= In Service Rate or percentage of units rebated that get installed* *= 1.00* [772]
WHFe	*= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.* *= Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Illustrative examples – do not use as default assumption

For example, a 1x4 fixture with 4ft F32 T8 2-Lamp and electronic ballast delivering 4,600 mean system lumens is replaced with an LED luminaire drawing 43W in a conditoned office building with gas heat in BGE service territory:[773]

$$\Delta kWh = ((53 - 43) / 1000) * 2{,}969 * 1.00 * 1.10$$

$$= 32.7 \text{ kWh}$$

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[770] 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.

[771] 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.

[772] 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.

[773] Wattage of illustrative LED luminaire developed by averaging the wattage for all DesignLights Consortium qualified high-bay products from the DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL> delivering between 80% and 100% of the baseline mean system lumens.

Summer Coincident Peak kW Savings Algorithm

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

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

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 1x4 fixture with 4ft F32 T8 2-Lamp and electronic ballast delivering 4,600 mean system lumens is replaced with an LED luminaire drawing 43W in a conditoned office building with gas heat in BGE service territory and estimating PJM summer peak coincidence:

$$\Delta kW = ((53 - 43) / 1000) * 1.00 * 1.32 * 0.69$$

$$= 0.01 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00065$$

Where:

0.7 = *Aspect ratio* [774]

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[774] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [775]

0.75 = Assumed heating system efficiency [776]

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.

Illustrative examples – do not use as default assumption

For examples, the incremental costs are approximately $100 for 1x4 (4,600 mean system lumens), $75 for 2x2 (4,100 mean system lumens), and $125 for 2x4 (6,900 mean system lumens) luminaires.[777]

Measure Life

The measure life is assumed to be 14 years.[778]

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. Estimated O&M savings should be calculated on a site-specific basis depending on the actual baseline and efficient equipment.

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[775] 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).

[776] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[777] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013.

[778] 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.

LED Parking Garage/Canopy Luminaires and Retrofit Kits*

Unique Measure Code(s): CI_LT_TOS_LEDODPG_0615 and CI_LT_RTR_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 List[779]..

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR$$

Where:

WattsBASE = Actual Connected load of baseline fixture
= If the actual baseline fixture wattage is unknown, use the default values presented in the "Parking Garage or Canopy Fixture Baseline and Efficient Wattage" table below.

WattsEE = Actual Connected load of the LED fixture
= If the actual LED fixture wattage is unknown, use the default values presented in the "Parking Garage or Canopy Fixture Baseline and Efficient Wattage" table below based on the based on the appropriate baseline description.

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[779] DesignLights Consortium Qualified Products List <https://www.designlights.org/QPL>

Parking Garage or Canopy Fixture Baseline and Efficient Wattage[780]

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*

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[780] 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.

applications[781]*. Otherwise, use site specific annual operating hours information.*[782]

ISR = *In Service Rate or percentage of units rebated that get installed*
= *1.00* [783]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta kWh = ((288 - 162) / 1000) * 8{,}760 * 1.00$$

$$= 1104 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0 for canopy applications and 1.0 for parking garage applications* [784]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

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[781] 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.

[782] 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.

[783] 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.

[784] 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.

$$\Delta kW = ((288 - 162) / 1000) * 1.00 * 1.00$$

$$= 0.13 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[785]

Measure Category	Installed Cost	Incremental Cost
Average of All Categories	$585	$343

Measure Life

The measure life is assumed to be 21 years for canopy applications and 8 years for parking garage applications.[786]

Operation and Maintenance Impacts[787]

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. Estimated O&M savings and the component cost and lifetime assumptions are presented in the table below.

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[785] Efficiency Maine Technical Reference User Manual No.2010-1, 2010.

[786] The average rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 3/13/2015 https://www.designlights.org/QPL 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.

[787] 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.

Measure Category	Baseline Description	Lamp Life (Hours)	Lamp Cost	Lamp Rep. Labor/Disposal Cost	Ballast Life (Hours)	Ballast Cost	Ballast Rep. Labor/Disposal Cost	NPV O&M Savings (Canopy/Parking Garage)
LED Parking Garage/Canopy Fixture replacing up to 175W HID	175W or less base HID	10000	$31.00	$2.92	40000	$95.85	$27.50	$194.46 / $156.09
LED Parking Garage/Canopy Fixture replacing 176-250W HID	176W up to 250W base HID	10000	$21.00	$2.92	40000	$87.75	$27.50	$142.93 / $133.33
LED Parking Garage/Canopy Fixture replacing 251 and above HID	251W and above base HID	10000	$11.00	$2.92	40000	$60.46	$27.50	$94.81 / $94.78

ENERGY STAR Integrated Screw Based SSL (LED) Lamp – Commercial**

Unique Measure Code: CI_LT_TOS_SSLDWN_0615
Effective Date: June 2015
End Date: TBD

Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp (specification effective September 30, 2014) in place of an incandescent lamp. The ENERGY STAR specification can be viewed here: http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

Definition of Baseline Condition

The baseline wattage is assumed to be an incandescent or EISA complaint (where appropriate) bulb installed in a screw-base socket.[788]

Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBase = *If actual LED lumens is known – find the equivalent baseline wattage from the table below*[789]

WattsEE = *LED Lamp Watts (if known).*

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*

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

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

Appendix D. Otherwise, use site specific annual operating hours information.[790]

ISR = *In Service Rate or percentage of units rebated that are installed and operational*

= *1.00* [791]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals	250	449	25
	450	799	29
	800	1099	43
	1100	1599	53
	1600	1999	72
	2000	2549	125
	2550	3000	150
	3001	3999	200
	4000	6000	300
3-Way	250	449	25
	450	799	40
	800	1099	60
	1100	1599	75
	1600	1999	100
	2000	2549	125
	2550	2999	150
Globe	90	179	10

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[790] 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.

[791] 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
(medium and intermediate bases less than 750 lumens)	180	249	15
	250	349	25
	350	749	40
Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)	70	89	10
	90	149	15
	150	299	25
	300	749	40
Globe (candelabra bases less than 1050 lumens)	90	179	10
	180	249	15
	250	349	25
	350	499	40
	500	1049	60
Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)	70	89	10
	90	149	15
	150	299	25
	300	499	40
	500	1049	60
Reflector with medium screw bases w/ diameter <=2.25"	400	449	40
	450	499	45
	500	649	50
	650	1199	65
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)	640	739	40
	740	849	45
	850	1179	50
	1180	1419	65
	1420	1789	75
	1790	2049	90
	2050	2579	100
	2580	3429	120
	3430	4270	150
R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26'' and ≤ 2.5" (*see exceptions below)	540	629	40
	630	719	45
	720	999	50
	1000	1199	65
	1200	1519	75
	1520	1729	90

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	1730	2189	100
	2190	2899	120
	2900	3850	150
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649-1179[792]	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps below lumen ranges specified above**	200	299	20
	300	399-639[793]	30

Illustrative example – do not use as default assumption

For example, a 10W 550 lumen LED directional lamp with medium screw base diameter <=2.25" is installed in a conditoned office building with gas heat in BGE service territory in 2015.

$$\Delta kWh = ((50 - 10)/ 1{,}000) * 2{,}969 * 1.00 * 1.10$$

$$= 131 \text{ kWh}$$

Baseline Adjustment

Currently the EISA legislation only applies to omnidirectional bulbs, with Decorative and Directional being exceptions. If additional legislation is passed, this TRM will be adjusted accordingly.

To account for these new standards, the savings for this measure should be reduced to account for the higher baselines in 2020. The following table shows the calculated adjustments for each measure type[794]:

Lower Lumen Range	Upper Lumen Range	Mid life Adjustment in 2020

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[792] The upper bounds for these categories depends on the lower bound of the next higher wattage, which varies by bulb type.

[793] As above.

[794] See 'ESTAR Integrated Screw SSL Lamp_032014.xls' for details.

200	449	100%
450	799	5%
800	1099	11%
1,100	1599	13%
1,600	1999	15%
2,000	2549	100%
2,550	3000	100%
3001	3999	100%
4000	6000	100%

Summer Coincident Peak kW Savings Algorithm

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

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

CF = *Summer Peak Coincidence Factor for measure*
= *See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.*

Illustrative example – do not use as default assumption

For example, a 10W 550 lumen LED directional lamp with medium screw base diameter <=2.25" is installed in a conditoned office building with gas heat in BGE service territory and estimating PJM summer peak coincidence.

$$\Delta kW = ((50 - 10)/ 1,000) * 1.0 * 0.69 * 1.32$$

$$= 0.036 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$
$= (-\Delta kWh / WHFe) * 0.00073$

Where:

0.7 = *Aspect ratio* [795]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [796]
0.75 = *Assumed heating system efficiency* [797]

Illustrative example – do not use as default assumption

For example, a 10W 550 lumen LED directional lamp with medium screw base diameter <=2.25" is installed a conditoned office building with gas heat in BGE service territory.

$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.00073$

$= - 0.087$ 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 incremental cost for this measure is presented below:[798]

Lamp Type	LED Wattage	Lamp Costs		Incremental Cost
		Efficient	Baseline	

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[795] 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.

[796] 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).

[797] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[798] All costs based on VEIC study of units rebated through the Efficiency Vermont Retail program and retail pricing from online, February 2015.

		LED	Incandescent	EISA 2012-2014 Compliant	Incandescent	EISA 2012-2014 Compliant
Omni-directional	<15W	$12.41	n/a	$1.50	n/a	$10.91
	>=15W	$24.26	n/a	$1.50	n/a	$22.76
Decorative	<15W	$12.76	$1.00	n/a	$11.76	n/a
	<=15 to <25W	$25.00	$1.00	n/a	$24.00	n/a
	>=25W	$25.00	$1.00	n/a	$24.00	n/a
Directional	<20W	$22.42	$5.00	n/a	$17.43	n/a
	>=20W	$70.78	$5.00	n/a	$65.78	n/a

Measure Life

The measure life is assumed to be:

Lamp Type	Rated Life[799]	Measure Life
		Commercial Interior
Omnidirectional	25,000	7
Decorative	15,000	4
Directional	25,000	7

Operation and Maintenance Impacts

For Decorative and Directional bulbs, without a baseline shift, the following component costs and lifetimes will be used to calculate O&M savings:

Lamp Type	Baseline Lamp Cost	Lamp Lifetime[800]
		Commercial Interior
Decorative	$3.40	0.29
Directional <15W	$6.16	0.29
Directional >=15W	$6.47	0.29

For Omni-directional bulbs, to account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the LED is calculated (see ‘MidAtlantic Lighting Adjustments and

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[799] The v1.1 ENERGY STAR Program Requirements for Lamps (Light Bulbs) requires SSL lamps to maintain >=70% initial light output for 25,000 hours for omnidirectional and directional bulbs, and 15,000 hrs for decorative bulbs. Assumes 3,500 average annual operating hours.

[800] Assumes incandescent baseline lamp life of 1000 hours.

O&M_042015.xls’). The key assumptions used in this calculation are documented below:

	EISA 2012-2014 Compliant	EISA 2020 Compliant
Replacement Cost <10W	$1.23	$2.86
Replacement Cost >=10W	$1.41	$3.19
Component Life (hours)	1000	10,000

LED Refrigerated Case Lighting**

Unique Measure Code(s): CI_LT_TOS_LEDRCL_0615 and CI_LT_RTR_LEDRCL_0615

Effective Date: June 2015

End Date: TBD

Measure Description

This measure relates to the installation of LED luminaries in vertical and horizontal refrigerated display cases replacing T8 or T12HO linear fluorescent lamp technology. Savings characterizations are provided for both coolers and freezers. Specified LED luminaires should meet v2.1 DesignLights Consortium Product Qualification Criteria for either the "Vertical Refrigerated Case Luminaire" or "Horizontal Refrigerated Case Luminares" 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

ΔkWh = (WattsPerLFBASE – WattsPerLFEE) / 1000 * LF * HOURS * WHFe

Where:

WattsPerLFBASE = Connected wattage per linear foot of the baseline fixtures; see table below for default values.[801]

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[801] Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

WattsPerLFEE = Connected wattage per linear foot of the LED fixtures.[802]
= 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.[803]

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.[804]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (WattsPerLFBASE - WattsPerLFEE) / 1000 * LF * WHFd * CF$$

Where:

WHFd = *Waste heat factor for demand to account for refrigeration savings from efficient lighting. For prescriptive refrigerated lighting measures, the default*

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[802] Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

[803] 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.

[804] 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.

value is 1.40 for refrigerated cases and 1.51 for freezer cases.[805]

CF = Summer Peak Coincidence Factor for measure
= 0.96 (lighting in Grocery).[806]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[807]

Efficient Measure Incremental Cost (TOS, NC)	
Application	**Cost per Foot ($/ft.)**
Vertical – Center	$28.43
Vertical – End	$21.10
Horizontal	$21.55

Efficient Measure Full Cost (Retrofit)	
Application	**Cost per Foot ($/ft.)**
Vertical – Center	$37.76
Vertical – End	$30.54
Horizontal	$31.15

Measure Life[808]

The expected measure life is assumed to be 8 years.

Operation and Maintenance Impacts

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[805] 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.

[806] 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.

[807] Navigant. May 2014. Incremental Cost Study Phase Three Final Report. Prepared for NEEP Regional Evaluation, Measurement & Verification Forum

[808] 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.

LED case lighting is expected to have a longer service life than the baseline T8 and T12HO fluorescent lighting systems. Estimated O&M savings should be calculated on a site-specific basis depending on the actual baseline and efficient equipment.

Exterior LED Flood and Spot Luminaires**

Unique Measure Code(s): CI_LT_TOS_LEDFLS_0615 and CI_LT_RTR_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.

Definition of Baseline Condition

The baseline condition is defined as an exterior flood or spot fixture with a high intensity discharge light-source. Typical baseline technologies include halogen incandescent parabolic aluminized reflector (PAR) lamps and metal halide (MH) luminaires.

Definition of Efficient Condition

The efficient condition is defined as an LED flood or spot luminaire. Eligible luminaires must be listed on the DesignLights Consortium Qualified Products List[809].

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.*[810]

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[809] DesignLights Consortium Qualified Products List <https://www.designlights.org/qpl>

[810] 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[811]	205.0

WattsEE = *Actual Connected load of the LED luminaire*
HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, assume 3,338* [812]. *Otherwise, use site specific annual operating hours information.*[813]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0* [814]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost of the LED luminaire is presented by lumen output in the table below.[815]

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[811] 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.

[812] Efficiency Vermont TRM User Manual No. 2014-85b; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[813] 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.

[814] It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

[815] Efficiency Vermont TRM User Manual No. 2014-85b.

Lower Lumen Range	Upper Lumen Range	Incremental Cost
500	1000	$150
1000	4000	$245
4000	15000	$315

Measure Life

The measure life is assumed to be 15 years.[816]

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.[817]

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[816] 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.

[817] 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_RTR_LEDTUBE_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:[818]

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 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

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[818] Underwriters Laboratories (UL) Standard 1598

(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.

Definition of Baseline Condition

The baseline condition is defined as an existing T8 linear fluorescent fixture with 32W, 28W, or 25W fluorescent lamps with a normal ballast factor electronic ballast.

Definition of Efficient Condition

The efficient condition is defined as an as an existing T8 linear fluorescent fixture with installed LED four-foot linear replacement lamp(s) and, if required, external driver. Eligible LED replacement lamp fixture wattage must be less than the baseline fucture wattage and listed on the DesignLights Consortium Qualified Products List[819].

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = Actual connected load of baseline fixture
= If actual baseline wattage is unknown, assume the “Delta Watts” from the table below based on existing lamp/ballast system.
WattsEE = Actual connected load of the fixture with LED replacement lamps.
= If actual baseline wattage is unknown, assume the “Delta Watts” from the table below based on existing lamp/ballast system.

Default Baseline and Efficient Lamp Wattage Assumptions[820]

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

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[819] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[820] 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.

25W T8 Premium PRS NLO	22	16	6

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.*[821] *Otherwise, use site specific annual operating hours information.*[822]

ISR = *In Service Rate or percentage of units rebated that get installed*
= *1.00* [823]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

Summer Coincident Peak kW Savings Algorithm

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

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. Otherwise, see table "Waste Heat Factors for C&I Lighting – Unknown HVAC Types" in Appendix D.*

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[821] 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.

[822] 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.

[823] Because of LED linear replacement lamps have not been specifically evaluated in the Mid-Atlantic region an initial ISR of 1.0 is assumed. However, costs of these products continue to drop rapidly increasing the probability that participants may purchase additional stock to be installed at a later date. This factor should be considered for future evaluation work.

CF = *Summer Peak Coincidence Factor for measure*
= *See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.*

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

Where:

0.7 = *Aspect ratio* [824]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [825]
0.75 = *Assumed heating system efficiency* [826]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs (equipment and labor) LED linear replacement lamps are as follows:[827]

Type A: $22.67 per LED replacement lamp, $47.50 for the ballast.
Type C: $22.67 per LED replacement lamp, $15.07 for the external driver.

Measure Life

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[824] 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.

[825] 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).

[826] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[827] 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).

The measure life is assumed to be 14 years.[828]

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.[829]

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[828] 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.

[829] 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

High Efficiency Unitary AC*

Unique Measure Code(s): CI_HV_TOS_UNIA/C_0615, CI_HV_EREP_UNIA/C_0615
Effective Date: June 2015
End Date: TBD

Measure Description

This measure documents savings associated with the installation of new split or packaged unitary air conditioning systems meeting defined efficiency criteria in place of an existing unitary air conditioner or a new standard efficiency unitary air conditioner of the same capacity. This measure applies to time of sale, new construction, and early replacement opportunities.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a split or packaged unitary air conditioning 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 and Efficient Efficiency Levels by Unit Capacity” below)[830].

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

Definition of Efficient Condition

The efficient condition is a split or packaged unitary air conditioning system meeting minimum Consortium for Energy Efficiency (CEE) Tier 1 or Tier 2[831] efficiency standards as defined below (see table “Baseline and Efficient Levels by Unit Capacity” below).

Baseline and Efficient Levels by Unit Capacity

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[830] While Washington, D.C., Delaware, and Maryland energy codes are based on different versions of the IECC, the requirements for air-cooled unitary air conditioners are consistent across the 2012 and 2015 versions.

[831] CEE Commercial Unitary AC and HP Specification, Effective January 6, 2012: http://www.cee1.org/files/CEE_CommHVAC_UnitarySpec2012.pdf

Equipment Type	Size Category	Subcategory	Baseline Condition (IECC 2012/2015)	Efficient Condition (CEE Tier 1)	Efficient Condition (CEE Tier 2)
Air Conditioners, Air Cooled	<65,000 Btu/h	Split system	13.0 SEER	14.0 SEER 12.0 EER	15.0 SEER 12.5 EER
		Single package	13.0 SEER	14.0 SEER 11.6 EER	15.0 SEER 12.0 EER
	≥65,000 Btu/h and <135,000 Btu/h	Split system and single package	11.2 EER 11.4 IEER	11.7 EER 13.0 IEER	12.2 EER 14.0 IEER
	≥135,000 Btu/h and <240,000 Btu/h	Split system and single package	11.0 EER 11.2 IEER	11.7 EER 12.5 IEER	12.2 EER 13.2 IEER
	≥240,000 Btu/h and <760,000 Btu/h	Split system and single package	10.0 EER 10.1 IEER	10.5 EER 11.3 IEER	10.8 EER 12.3 IEER
	≥760,000 Btu/h	Split system and single package	9.7 EER 9.8 IEER	9.9 EER 11.1 IEER	10.4 EER 11.6 IEER

Note: All table baseline and efficient ratings 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

Time of Sale:

For units with capacities less than 65,000 Btu/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

ΔkWh = (Btu/h/1000) * ((1/SEERBASE - 1/SEEREE)) * HOURS

For units with capacities greater than or equal to 65,000 Btu/h, the energy savings are calculated using the Energy Efficiency Ratio (EER) as follows:

ΔkWh = (Btu/h/1000) * ((1/IEERBASE - 1/IEEREE)) * HOURS

Early Replacement[832]:

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[832] 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

For units with capacities less than 65,000 Btu/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

ΔkWh for remaining life of existing unit (i.e., measure life less the age of the existing equipment):
= (Btu/h/1000) * ((1/SEEREXIST - 1/SEEREE)) * HOURS

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):
= (Btu/h/1000) * ((1/SEERBASE - 1/SEEREE)) * HOURS

For units with capacities greater than or equal to 65,000 Btu/h, the energy savings are calculated using the Energy Efficiency Ratio (EER) as follows:

ΔkWh for remaining life of existing unit (i.e., measure life less the age of the existing equipment):
= (Btu/h/1000) * ((1/IEEREXIST - 1/IEEREE)) * HOURS

ΔkWh for remaining measure life (i.e., measure life less the remaining life of existing unit):
= (Btu/h/1000) * ((1/IEERBASE - 1/IEEREE)) * HOURS

Where:

Btu/h = *Cooling capacity of equipment in BTU/hour*
= *Actual Installed*
SEEREE = *SEER Efficiency of efficient unit*
= *Actual Installed*
SEERBASE = *SEER Efficiency of baseline unit*
= *Based on IECC 2012/2015 for the installed capacity. See table above.*
SEEREXIST = *SEER Efficiency of the existing unit.*
IEEREE = *IEER Efficiency of efficient unit*
= *Actual Installed*
IEERBASE = *IEER Efficiency of baseline unit*
= *Based on IECC 2012/2015 for the installed capacity. See table above.*
IEEREXIST = *IEER Efficiency of the existing unit.*

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savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

HOURS = *Full load cooling hours*[833]
= *If actual full load cooling hours are unknown, see table "Full Load Cooling Hours by Location and Equipment Capacity" below. Otherwise, use site specific full load cooling hours information.*

Full Load Cooling Hours by Location and Equipment Capacity[834]

City, State	HOURS by Equipment Capacity	
	< 135 kBtu/h	>= 135 kBtu/h
Dover, DE	910	1,636
Wilmington, DE	980	1,762
Baltimore, MD	1,014	1,823
Hagerstown, MD	885	1,591
Patuxent River, MD	1,151	2,069
Salisbury, MD	1,008	1,812
Washington D.C.	1,275	2,292

For example, a 5 ton unit with SEER rating of 14.0 installed in Baltimore:

$$\Delta kWh = (60{,}000/1000) * (1/13 - 1/14) * 1014$$

$$= 334 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

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

[834] Full load cooling hours estimated by adjusting the "Mid-Atlantic" hours from "C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011" by the full-load cooling hour estimates from the ENERGY STAR Central AC Calculator, 2013. For scaling purposes, the analysis assumes the initial Mid-Atlantic values are consistent with Baltimore, MD as suggested by the KEMA study. Because the ENERGY STAR calculator does not provide full load hours estimates for all cities of interest, a second scaling was performed using cooling degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

$\Delta kW = (Btu/h/1000) * ((1/EERBASE - 1/EEREE)) * CF$

Early Replacement:

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

$= (Btu/h/1000) * ((1/EEREXIST - 1/EEREE)) * CF$

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

$= (Btu/h/1000) * ((1/EERBASE - 1/EEREE)) * CF$

Where:

EERBASE = EER Efficiency of baseline unit
= Based on IECC 2012/2015 for the installed capacity. See table above.

EEREE = EER Efficiency of efficient unit
= Actual installed

EEREXIST = EER Efficiency of existing unit

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[835]

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[836]

For example, a 5 ton unit with EER rating of 12 installed in Baltimore estimating PJM summer peak coincidence:[837]

$\Delta kW = (60{,}000/1000) * (1/10.8 - 1/12) * 0.360$

$= 0.20$ kW

Annual Fossil Fuel Savings Algorithm

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

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

[837] Assumes baseline unit with 13 SEER converted to EER using the following estimate: EER = SEER/1.2

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[838]

The incremental costs are shown in the tables below for time of sale and new construction scenarios. 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 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.

Size Category	Efficient Condition (CEE Tier 1)	Efficient Condition (CEE Tier 2)
>=65,000 Btu/h and <135,000	$62.96/ton	$125.92/ton
>=135,000 Btu/h and <240,000 Btu/h	$62.96/ton	$125.92/ton
>=240,000 Btu/h and <760,000 Btu/h	$18.78/ton	$37.56/ton

Measure Life

The measure life is assumed to be 15 years.[839]

Operation and Maintenance Impacts

n/a

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[838] Navigant. May 2014. Incremental Cost Study Phase Three Final Report. Prepared for NEEP Regional Evaluation, Measurement & Verification Forum. In all cases, incremental costs are presented relative to the baseline efficiencies presented in the Baseline and Efficient Levels by Unit Capacity Table for the relevant size categories.

[839] 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

Variable Frequency Drive (VFD) for HVAC*

Unique Measure Code(s): CI_MO_RTR_VFDRIVE_0615
Effective Date: June 2015
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 boiler feedwater 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 (Two–way valves, VAV boxes) must be installed.

Definition of Baseline Condition

The baseline condition is a motor, 200 hp or less, without a VFD control.

Definition of Efficient Condition

The efficient condition is a motor, 200 hp or less, with a VFD control.

Annual Energy Savings Algorithm

$$\Delta kWh = ((HP * 0.746 * LF) / \eta BASE) * HOURS * ESF$$

Where:

HP = *Nameplate motor horsepower*
= *Actual nameplate motor horsepower*
0.746 = *kWh per hp conversion factor*
LF = *Motor load factor (%) at fan design CFM or pump design GPM*
= *If actual load factor is unknown, assume 75%. Otherwise, use site-specific load factor information.*
ηBASE = *Efficiency of VFD-driven motor*
= *Actual efficiency*
HOURS = *Annual hours of operation*
= *If actual operating hours are unknown, see table "VFD Operating Hours by Application and Building Type" below. Otherwise, use site specific operating hours information.*

ESF = *Energy Savings Factor (see table "Energy and Demand Savings Factors" below)*

Illustrative examples – do not use as default assumption

For example, a 10 hp motor with VFD used on supply fan application in an office (assume 90% motor efficiency, 75% load factor, and constant volume baseline control):

$$\Delta kWh = ((10 * 0.746 * 0.75) / 0.9) * 3{,}748 * 0.717$$

$$= 16{,}706 \text{ kWh}$$

VFD Operating Hours by Application and Building Type[840]

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Auto Related	4,056	1,878	5,376
Bakery	2,854	1,445	5,376
Banks, Financial Centers	3,748	1,767	5,376
Church	1,955	1,121	5,376
College – Cafeteria	6,376	2,713	5,376
College - Classes/Administrative	2,586	1,348	5,376
College - Dormitory	3,066	1,521	5,376
Commercial Condos	4,055	1,877	5,376
Convenience Stores	6,376	2,713	5,376
Convention Center	1,954	1,121	5,376
Court House	3,748	1,767	5,376
Dining: Bar Lounge/Leisure	4,182	1,923	5,376
Dining: Cafeteria / Fast Food	6,456	2,742	5,376
Dining: Family	4,182	1,923	5,376
Entertainment	1,952	1,120	5,376
Exercise Center	5,836	2,518	5,376
Fast Food Restaurants	6,376	2,713	5,376
Fire Station (Unmanned)	1,953	1,121	5,376
Food Stores	4,055	1,877	5,376
Gymnasium	2,586	1,348	5,376
Hospitals	7,674	3,180	5,376
Hospitals / Health Care	7,666	3,177	5,376
Industrial - 1 Shift	2,857	1,446	5,376

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[840] United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8th Edition for 2013 Program Year. Orange, CT.

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
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	5,376
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	5,376
Office (General Office Types)	3,748	1,767	5,376
Office/Retail	3,748	1,767	5,376
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	5,376
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	5,376
School / University	2,187	1,205	5,376
Schools (Jr./Sr. High)	2,187	1,205	5,376
Schools (Preschool/Elementary)	2,187	1,205	5,376
Schools (Technical/Vocational)	2,187	1,205	5,376
Small Services	3,750	1,768	5,376
Sports Arena	1,954	1,121	5,376
Town Hall	3,748	1,767	5,376
Transportation	6,456	2,742	5,376
Warehouse (Not Refrigerated)	2,602	1,354	5,376
Waste Water Treatment Plant	6,631	2,805	5,376
Workshop	3,750	1,768	5,376

Energy and Demand Savings Factors[841]

HVAC Fan VFD Savings Factors		
Baseline	**ESF**	**DSF**
Constant Volume	0.717	0.466
AF/BI	0.475	0.349
AF/BI IGV	0.304	0.174
FC	0.240	0.182
FC IGV	0.123	0.039
HVAC Pump VFD Savings Factors		
System	**ESF**	**DSF**
Chilled Water Pump	0.580	0.401
Hot Water Pump	0.646	0.000

AF/BI = Air foil / backward incline
AF/BI IGV = AF/BI Inlet guide vanes
FC = Forward curved
FC IGV = FC Inlet guide vanes

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((HP * 0.746 * LF) / \eta BASE) * DSF * CF$$

Where:

DSF = Demand Savings Factor (see table "Energy and Demand Savings Factors" above)

CF = Summer Peak Coincidence Factor for measure
= 0.55 (pumps) and 0.28 (fans) [842]

Illustrative examples – do not use as default assumption

For example, a 10 hp motor with VFD used on supply fan application in an office (assume 90% motor efficiency, 80% load factor, and constant volume baseline control):

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[841] 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.

[842] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives – Pumps.

$$\Delta kW = ((10 * 0.746 * 0.75)/ 0.9) * 0.466 * 0.28$$

$$= 0.81 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure varies by controlled motor hp. See table "VFD Incremental Costs" below.

VFD Incremental Costs[843]

Rated Motor Horsepower (HP)	Total Installed Costs
5	$2,125
15	$3,193
25	$4,260
50	$6,448
75	$8,407
100 [844]	$10,493
200 [845]	$17,266

Measure Life

The measure life is assumed to be 15 years for HVAC applications.[846]

Operation and Maintenance Impacts

n/a

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[843] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

[844] The Incremental Cost Study does not provide labor cost estimates for units 100 hp and above. Labor cost estimates derived from RSMeans Mechanical Cost Data 2010. US average labor costs for 100 hp and 200 hp units adjusted to the Mid-Atlantic region using population weighted (2010 Census) "Location Factors" from RSMeans.

[845] Ibid.

[846] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

Electric Chillers*

Unique Measure Code: CI_HV_TOS_ELCHIL_0615, CI_HV_EREP_ELCHIL_0615
Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the installation of a new high-efficiency electric water chilling package in place of an existing chiller or a new standard efficiency chiller of the same capacity. This measure applies to time of sale, new construction, and early replacement opportunities.

Definition of Baseline Condition

Time of Sale or New Construction: For Washington, D.C. and Delaware, the baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2012 (IECC 2012), Table C403.2.3(7). For Maryland, the baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2015 (IECC 2015), Table C403.2.3(7).

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

Definition of Efficient Condition

For Washington, D.C. and Delaware, the efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2012 (IECC 2012), Table C403.2.3(7). For Maryland, the efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2015 (IECC 2015), Table C403.2.3(7).

Annual Energy Savings Algorithm

Time of Sale and New Construction:

$$\Delta kWh = TONS * (IPLVbase - IPLVee) * HOURS$$

Early Replacement[847]:

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

= TONS * (IPLVexist - IPLVee) * HOURS

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

= TONS * (IPLVbase - IPLVee) * HOURS

Where:

TONS = Total installed capacity of the water chilling package[tons]

= Actual Installed

IPLVexist = Integrated Part Load Value (IPLV)[848] of the existing equipment [kW/ton]

IPLVbase = Integrated Part Load Value (IPLV) of the new baseline equipment [kW/ton]

= Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below[849]

IPLVee = Integrated Part Load Value (IPLV) of the efficient equipment [kW/ton]

= Actual Installed

HOURS = Full load cooling hours

= If actual full load cooling hours are unknown, assume values presented in table "Default Electric Chiller Full Load Cooling Hours" in the "Reference Tables" section below. Otherwise, use site specific full load cooling hours information.

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[847] 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.

[848] Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

[849] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages and International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Packages - Efficiency Requirements

Summer Coincident Peak kW Savings Algorithm

Time of Sale and New Construction:

ΔkW = TONS * (Full_Loadbase - Full_Loadee) * CF

Early replacement:

ΔkW for remaining life of existing unit (i.e., measure life less the age of the existing equipment):
= TONS * (Full_Loadexist - Full_Loadee) * CF

ΔkW for remaining measure life (i.e., measure life less the remaining life of existing unit):
= TONS * (Full_Loadbase - Full_Loadee) * CF

Where:

Full_Loadexist = Full load efficiency of the existing equipment [kW/ton]

Full_Loadbase = Full load efficiency of the baseline equipment [kW/ton]
= Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below[850]

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[851]

CF_{SSP} *= Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= 0.923[852]

Annual Fossil Fuel Savings Algorithm

n/a

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[850] 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

[851] 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.

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

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs for chillers are shown in the tables below for time of sale and new construction scenarios.[853] 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 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.

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	$258	$486	$730	$867
100	9.562	$128	$243	$364	$433
150	9.562	$86	$162	$244	$289
200	9.562	$53	$99	$149	$177
400	9.562	$26	$50	$74	$88

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	$76	$320	$457
100	10.1	N/A	$38	$159	$228
150	10.1	N/A	$25	$107	$152
200	10.1	N/A	$15	$65	$93
400	10.1	N/A	$8	$32	$46

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[853] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA. Table values adapted from published values to align with baseline code requirements ("Path A") by interpolating or extrapolating from nearest pair of published efficiency values. "N/A" indicates either an efficiency value below baseline requirements or a gap in the published data from the source document.

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	$114	$164	N/A	N/A
100	0.775	$52	$77	N/A	N/A
150	0.68	N/A	N/A	N/A	N/A
200	0.68	N/A	N/A	$61	$122
400	0.62	N/A	N/A	N/A	$16

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	$57	$107	N/A	N/A
100	0.72	$0	$25	N/A	N/A
150	0.66	N/A	N/A	N/A	N/A
200	0.66	N/A	N/A	$31	$92
400	0.61	N/A	N/A	N/A	$8

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	$62	$99	$172
150	0.634	$42	$66	$115
200	0.634	$31	$49	$86
300	0.576	N/A	N/A	$55
600	0.57	N/A	N/A	$22

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	$18	$55	$128
150	0.61	$12	$36	$85
200	0.61	$9	$27	$64
300	0.56	N/A	N/A	$31

Capacity (Tons)	Baseline kW/ton	Efficient kW/ton		
		0.6	0.58	0.54
600	0.56	N/A	N/A	$15

Measure Life

The measure life is assumed to be 23 years[854].

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency for Washington, D.C. and Delaware[855]

Equipment Type	Size Category	Units	Path A[a]		Path B[a]	
			Full Load	IPLV	Full Load	IPLV
Air-Cooled Chillers	<150 tons	EER	≥9.562	≥12.500	NA	NA
	≥150 tons	EER	≥9.562	≥12.750	NA	NA
Water Cooled, Electrically Operated, Positive Displacement	<75 tons	kW/ton	≤0.780	≤0.630	≤0.800	≤0.600
	≥75 tons and <150 tons	kW/ton	≤0.775	≤0.615	≤0.790	≤0.586
	≥150 tons and <300 tons	kW/ton	≤0.680	≤0.580	≤0.718	≤0.540
	≥300 tons	kW/ton	≤0.620	≤0.540	≤0.639	≤0.490
Water Cooled, Electrically Operated, Centrifugal	<150 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥150 tons and <300 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥300 tons and <600 tons	kW/ton	≤0.576	≤0.549	≤0.600	≤0.400
	≥600 tons	kW/ton	≤0.570	≤0.539	≤0.590	≤0.400

a. Compliance with IECC 2012 can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.

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[854] 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"

[855] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages.

Time of Sale Baseline Equipment Efficiency for Maryland[856]

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.

Default Electric Chiller Full Load Cooling Hours[857]

Building Type	System Type[a]	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Community College	CAV w/o economizer	1,010	1,048	1,121	1,044	1,202	1,117	1,274
Community College	CAV w/ economizer	752	781	836	777	897	833	952
Community College	VAV w/ economizer	585	607	649	605	695	647	736

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[856] Baseline efficiencies based on International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Package - Efficiency Requirements.

[857] 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 cooling degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

Building Type	**System Type**[a]	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
High School	CAV w/o economizer	819	830	851	829	875	850	896
High School	CAV w/ economizer	428	440	463	439	489	462	511
High School	VAV w/ economizer	306	316	336	315	359	335	379
Hospital	CAV w/o economizer	2,094	2,135	2,213	2,130	2,302	2,210	2,379
Hospital	CAV w/ economizer	1,307	1,341	1,406	1,338	1,479	1,403	1,543
Hospital	VAV w/ economizer	1,142	1,165	1,208	1,162	1,257	1,206	1,300
Hotel	CAV w/o economizer	3,166	3,165	3,163	3,165	3,161	3,163	3,159
Hotel	CAV w/ economizer	2,972	2,972	2,971	2,972	2,971	2,971	2,971
Hotel	VAV w/ economizer	2,953	2,958	2,967	2,957	2,977	2,966	2,986
Large Retail	CAV w/o economizer	1,719	1,730	1,750	1,729	1,772	1,749	1,792
Large Retail	CAV w/ economizer	987	1,011	1,057	1,009	1,109	1,055	1,155
Large Retail	VAV w/ economizer	817	838	877	835	921	875	959
Office Building	CAV w/o economizer	2,162	2,193	2,252	2,189	2,318	2,249	2,377
Office Building	CAV w/ economizer	700	710	729	709	750	728	768
Office Building	VAV w/ economizer	670	685	716	684	749	714	779
University	CAV w/o economizer	1,103	1,135	1,198	1,132	1,267	1,194	1,329
University	CAV w/ economizer	796	822	871	819	925	868	974
University	VAV w/ economizer	626	645	682	643	724	680	760

a. “CAV” refers to constant air volume systems whereas “VAV” refers to variable air volume systems.

Gas Boiler

Unique Measure Code: CI_HV_TOS_GASBLR_0614 and CI_HV_RTR_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 85% AFUE for units <300 kBtu/h and 85% E_t for units >300 kBtu/h. See the "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = CAP * HOURS * (1/EFF_{base} - 1/EFF_{ee}) / 1,000,000$$

Where:

CAP = *Equipment capacity [Btu/h]*
= *Actual Installed*
HOURS = *Full Load Heating Hours*

= See "Heating Full Load Hours" table in the "Reference Tables" section below[858]

EFF_{base} *= The efficiency of the baseline equipment; Can be expressed as thermal efficiency (E_t), combustion efficiency (E_c), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.*

= For time of sale: See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below[859]

equipment

EFF_{ee} *= The efficiency of the efficient equipment; Can be expressed as thermal efficiency (E_t), combustion efficiency (E_c), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.*

= Actual Installed

1,000,000 *= Btu/MMBtu unit conversion factor*

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure varies by size category and efficiency level. See the "Time of Sale Incremental Costs" table in the "Reference Tables" section below.

Measure Life

The measure life is assumed to be 20 years[860].

Operation and Maintenance Impacts

n/a

Reference Tables

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[858] 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.

[859] 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.

[860] Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

Time of Sale Baseline Equipment Efficiency[861]

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency
Boilers, Gas-fired	<300,000 Btu/h	Hot water	82% AFUE
		Steam	80% AFUE
	>=300,000 Btu/h and <=2,500,000 Btu/h	Hot water	80% E_t
		Steam - all, except natural draft	79.0% E_t
		Steam - natural draft	77.0% E_t
	>2,500,000 Btu/h	Hot water	82.0% E_c
		Steam - all, except natural draft	79.0% E_t
		Steam - natural draft	77.0% E_t

Time of Sale Incremental Costs[862]

Size Category (kBtu/h)	Incremental Cost		Efficiency Metric
	>=85% and <90% Efficiency	>=90% Efficiency	
<300	$934	$1481	AFUE
300	$572	$3,025	E_t
500	$1,267	$3,720	E_t
700	$1,962	$4,414	E_t
900	$2,657	$5,109	E_t
1,100	$3,352	$5,804	E_t

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[861] Baseline efficiencies based on current federal standards: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf.

[862] For units <300 kBtu/h, costs derived from Page E-13 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document: http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html VEIC believes it is reasonable to assume that the cost provided from this study for an 85% unit is appropriate for units in the 85-90% AFUE range and the cost for the 91% unit can be used for 91+% units. This is based on the observation that most of the products available in the 85-90 range are in the lower end of the range, as are those units available above 91% AFUE. For units >= 300 kBtu/h costs adopted from the Northeast Energy Efficiency Partnerships Incremental Cost Study Report, Navigant, 2011.

1,300	$4,047	$6,499	E_t
1,500	$4,742	$7,194	E_t
1,700	$5,436	$7,889	E_t
2,000	$6,479	$8,931	E_t
>=2200	$7,174	$9,626	E_t

Heading Full Load Hours[863]

Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	676	692	620	657	451	507	559
Auto Repair	2,292	2,344	2,106	2,229	1,543	1,728	1,901
Big Box Retail	286	298	241	271	107	151	192
Fast Food Restaurant	957	983	866	926	590	681	766
Full Service Restaurant	988	1,016	891	956	597	694	784
Grocery	286	298	241	271	107	151	192
Light Industrial	867	885	803	845	608	672	732
Motel	659	667	632	650	547	575	601
Primary School	978	993	926	960	767	819	868
Religious Worship	750	754	737	746	698	711	723
Small Office	511	524	466	496	329	374	416
Small Retail	657	674	595	636	410	471	528
Warehouse	556	576	487	533	278	347	411
Other	805	823	739	783	541	606	667

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[863] 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.

Gas Furnace*

Unique Measure Code: CI_HV_TOS_GASFUR_0615, CI_HV_RTR_GASFUR_0615

Effective Date: June 2015
End Date: TBD

Measure Description

This measure relates to the installation of a high efficiency gas furnace with capacity less than 225,000 Btu/h with an electronically commutated fan motor (ECM) in the place of a standard efficiency gas furnace. This measure applies to time of sale and new construction opportunities.

Definition of Baseline Condition

Time of Sale: The baseline condition is a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 80% with a standard efficiency furnace fan.

Definition of Efficient Condition

The efficient condition is a high-efficiency gas furnace with an AFUE of 90% or higher. This characterization only applies to furnaces with capacities less than 225,000 Btu/h with an electronically commutated fan motor (ECM).

Annual Energy Savings Algorithm[864]

$$\Delta kWh = 733\ kWh$$[865]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0.19\ kW$$[866]

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = CAP * HOURS * ((1/AFUE_{base}) - (1/AFUE_{ee})) / 1{,}000{,}000$$

Where:

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[864] Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

[865] 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.

[866] Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.

CAP = *Capacity of the high-efficiency equipment [Btu/h]*
= *Actual Installed*
HOURS = *Full Load Heating Hours*
= *See "Heating Full Load Hours" table in the "Reference Tables" section below*[867]
$AFUE_{base}$ = *Annual Fuel Utilization Efficiency of the baseline equipment*
= *For time of sale: 0.80*[868]
$AFUE_{ee}$ = *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 incremental cost for this measure is provided below[869]:

Efficiency of Furnace (AFUE)	Incremental Cost
90%	$630
92%	$802
96%	$1,747

Measure Life

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[867] 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.

[868] 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.

[869] Costs derived from Page E-3 of Appendix E of Residential Furnaces and Boilers Final Rule Technical Support Document:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/fb_tsd_0907.html

The measure life is assumed to be 18 years[870].

Operation and Maintenance Impacts

n/a

Reference Tables

Heating Full Load Hours[871]

Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	676	692	620	657	451	507	559
Auto Repair	2,292	2,344	2,106	2,229	1,543	1,728	1,901
Big Box Retail	286	298	241	271	107	151	192
Fast Food Restaurant	957	983	866	926	590	681	766
Full Service Restaurant	988	1,016	891	956	597	694	784
Grocery	286	298	241	271	107	151	192
Light Industrial	867	885	803	845	608	672	732
Motel	659	667	632	650	547	575	601
Primary School	978	993	926	960	767	819	868
Religious Worship	750	754	737	746	698	711	723
Small Office	511	524	466	496	329	374	416
Small Retail	657	674	595	636	410	471	528
Warehouse	556	576	487	533	278	347	411
Other	805	823	739	783	541	606	667

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[870] 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"

[871] 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

Dual Enthalpy Economizer

Unique Measure Code: CI_HV_RTR_DEECON_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure involves the installation of a dual enthalpy economizer to provide free cooling during the appropriate ambient conditions. Enthalpy refers to the total heat content of the air. A dual enthalpy economizer uses two sensors — one measuring return air enthalpy and one measuring outdoor air enthalpy. Dampers are modulated for optimum and lowest enthalpy to be used for cooling. This measure applies only to retrofits.

Definition of Baseline Condition

The baseline condition is the existing HVAC system with no economizer.

Definition of Efficient Condition

The efficient condition is the HVAC system with dual enthalpy controlled economizer.

Annual Energy Savings Algorithm

$$\Delta kWh = TONS * SF$$

Where:

TONS = Actual Installed

SF = Savings factor for the installation of dual enthalpy economizer control [kWh/ton],
= See "Savings Factors" table in "Reference Tables" section below[872]

Summer Coincident Peak kW Savings Algorithm

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[872] 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.

$\Delta kW = 0\ kW$[873]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental costs for this measure are presented in the “Dual Enthalpy Economizer Incremental Costs” table below.

Dual Enthalpy Economizer Incremental Costs[874]

HVAC System Capacity (Tons)	Incremental Cost
5	$943
15	$1,510
25	$2,077
40	$2,927
70	$4,628

Measure Life

The measure life is assumed to be 10 years[875].

Operation and Maintenance Impacts

n/a

Reference Tables

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[873] Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

[874] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

[875] General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

Savings Factors[876]

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	144	125	143	165	141	155	139
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	177	153	175	201	173	189	171
Small Retail	90	78	89	103	88	97	87
Religious	6	5	6	6	6	6	6
Warehouse	2	2	2	2	2	2	2
Other	58	50	57	66	57	62	56

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[876] kWh/ton savings from NY Standard Approach Model, with scaling factors based on enthalpy data from NYC and Mid-Atlantic cities.

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

A ductless mini-split heat pump (DSMHP) 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.[877] 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 14.5 SEER, 12.0 EER, and 8.2 HSPF. If the rated efficiency of the actual unit is higher than the ENERGY STAR

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[877] 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.

minimum requirements, the actual efficiency ratings should be used in the calculation.

Baseline and Efficient Levels by Unit Capacity

If the measure is a retrofit, the actual efficiencies of the baseline heating and cooling equipment should be used. If it is a market opportunity, the baseline efficiency should be selected from the tables below.

Baseline Window AC Efficiency[878]

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[879]	All	13	11
Packaged Air Conditioners[880]	All	14	11.5
Packaged Air Source Heat Pumps[881]	All	14	11.5

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[878] Federal standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

[879] Federal Standard as of January 1, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

[880] Ibid

[881] Ibid

Baseline Heating System Efficiency

Equipment Type	Efficiency Metric	Efficiency
Gas Boiler[882]	AFUE	82%
Air Source Heat Pump – Split System[883]	HSPF	8.2
Air Source Heat Pump - Packaged	HSPF	8.0
Electric Resistance[884]	HSPF	3.41

Annual Energy Savings Algorithm

$$\Delta kWh_{total} = \Delta kWh_{cool} + \Delta kWh_{heat}$$
$$\Delta kWh_{cool} = CCAP \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}$$
$$\Delta kWh_{heat}{}^{885} = HCAP \times (ELECHEAT/HSPF_{base} - 1/HSPF_{ee}) \times EFLH_{heat}$$

Where:

CCAP = Cooling capacity of DMSHP unit, in kBTU/hour
$SEER_{base}$ = SEER of baseline unit. If unknown, use 9.8[886]*.*
$SEER_{ee}$ = SEER of actual DMSHP. If unknown, use ENERGY STAR minimum of 14.5.
$EFLH_{cool}$ = Full load hours for cooling equipment. See table below for default values.
HCAP = Heating capacity of DMSHP unit, in kBTU/hour
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[887]*.*
$HSPF_{ee}$ = HSPF of actual DMSHP. If unknown, use ENERGY STAR minimum of 8.2.
$EFLH_{heat}$ = Full load hours for heating equipment. See table below for default values.

Full Load Cooling Hours by Location and Equipment Capacity[888]

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[882] Federal Standards for gas boilers

[883] Federal standards for air source heat pumps

[884] Electric heat has a COP of 1.0. Converted into HSPF units this is approximately 3.41.

[885] 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.

[886] Federal standard for typical window AC sizes with louvered sides.

[887] If unknown, assume the baseline is a gas furnace, with no electrical savings

[888] Full load cooling hours estimated by adjusting the “Mid-Atlantic” hours from “C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011” by the full-load cooling hour estimates from the ENERGY STAR Central AC Calculator, 2013. For scaling purposes, the analysis assumes

City, State	HOURS by Equipment Capacity	
	< 135 kBtu/h	>= 135 kBtu/h
Dover, DE	910	1,636
Wilmington, DE	980	1,762
Baltimore, MD	1,014	1,823
Hagerstown, MD	885	1,591
Patuxent River, MD	1,151	2,069
Salisbury, MD	1,008	1,812
Washington D.C.	1,275	2,292

Heating Full Load Hours[889]

Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	676	692	620	657	451	507	559
Auto Repair	2,292	2,344	2,106	2,229	1,543	1,728	1,901
Big Box Retail	286	298	241	271	107	151	192
Fast Food Restaurant	957	983	866	926	590	681	766
Full Service Restaurant	988	1,016	891	956	597	694	784
Grocery	286	298	241	271	107	151	192
Light Industrial	867	885	803	845	608	672	732
Motel	659	667	632	650	547	575	601
Primary School	978	993	926	960	767	819	868
Religious Worship	750	754	737	746	698	711	723
Small Office	511	524	466	496	329	374	416
Small Retail	657	674	595	636	410	471	528

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the initial Mid-Atlantic values are consistent with Baltimore, MD as suggested by the KEMA study. Because the ENERGY STAR calculator does not provide full load hours estimates for all cities of interest, a second scaling was performed using cooling degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

[889] 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

Building Type	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Warehouse	556	576	487	533	278	347	411
Other	805	823	739	783	541	606	667

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = CCAP \times (1/EER_{base} - 1/EER_{ee}) \times CF$$

Where:

EER_{base} = *EER of baseline unit. If unknown, use 9.8*[890].

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*[891]

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*[892]

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBtu = HCAP \times EFLH_{heat} / AFUE / 1{,}000$$

Where:

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[890] Federal standard for typical window AC sizes with louvered sides.

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

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

$EFLH_{heat}$ = *Full load hours for heating equipment. See table above.*

AFUE = *AFUE of baseline equipment. If unknown use 82%[893].*

Incremental Cost

The full installed cost of the ductless mini-split system is shown below[894].

Capacity (kBtu/h)	Efficiency			
	13 SEER	18 SEER	21 SEER	26 SEER
9	$2,733	$3,078	$3,236	$3,460
12	$2,803	$3,138	$3,407	$3,363
18	$3,016	$3,374	$3,640	N/A
24	$3,273	$3,874	N/A	N/A

The full installed cost of the baseline equipment is shown below.

Unit	Cost
Window AC[895]	$170/unit
Gas furnace[896]	$1,606/unit
Electric Baseboard[897]	$0

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.

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[893] Federal standard for gas boilers.

[894] Navigant, Inc. Incremental Cost Study Phase 2. January 16, 2013. Table 16.

[895] Energy Star Calculator. http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls)

[896] 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

[897] If existing case is electric resistance heat, assume project replaces existing functional baseboard.

Measure Life

The measure life for a DSMHP is 18 years.[898]

Operation and Maintenance Impacts

n/a

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[898] 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.

AC Tune-Up**

Unique Measure Code(s): CI_HV_RET_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[899]. For smaller units, tuning measures may include:

- Refrigerant charge correction
- Cleaning the condensate drain line
- Clean and straighten coils and fans
- Replace air filter
- Repair damaged insulation

Definition of Baseline Condition

The baseline condition is a pre-tune-up air conditioner. Where possible, spot measurements should be used to estimate the baseline EER. An HVAC system is eligible for a tune-up once every five years.

Definition of Efficient Condition

The efficient condition is a post-tune-up air conditioner. Where possible, spot measurements should be used to estimate the EER post-tune-up.

Annual Energy Savings Algorithm

$$\Delta kWh = CCAP \times EFLH \times 1/SEER_{pre} \times \%\_impr$$

Where:

CCAP = Cooling capacity of existing AC unit, in kBTU/hour

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[899] 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.*[900]

Full Load Cooling Hours by Location and Equipment Capacity[901]

City, State	HOURS by Equipment Capacity	
	< 135 kBtu/h	>= 135 kBtu/h
Dover, DE	910	1,636
Wilmington, DE	980	1,762
Baltimore, MD	1,014	1,823
Hagerstown, MD	885	1,591
Patuxent River, MD	1,151	2,069
Salisbury, MD	1,008	1,812
Washington D.C.	1,275	2,292

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/hour*

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*

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[900] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[901] Full load cooling hours estimated by adjusting the "Mid-Atlantic" hours from "C&I Unitary HVAC Load Shape Project Final Report, KEMA, 2011" by the full-load cooling hour estimates from the ENERGY STAR Central AC Calculator, 2013. For scaling purposes, the analysis assumes the initial Mid-Atlantic values are consistent with Baltimore, MD as suggested by the KEMA study. Because the ENERGY STAR calculator does not provide full load hours estimates for all cities of interest, a second scaling was performed using cooling degree day estimates from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

onsite testing data is not available, assumed %_impr = 0.05.[902]

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[903]

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[904]

Annual Fossil Fuel Savings Algorithm

n/a

Incremental Cost

Use the actual cost of the tune-up. If this is unknown, use a default of $35/ton[905].

Measure Life

The measure life for an AC tune-up is 5 years.[906]

Operation and Maintenance Impacts

n/a

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[902] Energy Center of Wisconsin, May 2008; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.”

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

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

[905] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 4.0 Final February 24 2015

[906] 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 2.1 requirements[907].

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) * 365$$

Where:

kWhBASEdailymax [908] = *See table below.*

Product Volume (in cubic feet)	kWhBASEdailymax
Solid Door Cabinets	0.40V + 1.38
Glass Door Cabinets	0.75V + 4.10

Where V = Association of Home Appliances Manufacturers (AHAM) volume

kWhEEdailymax [909] = *See table below.*

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[907] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 2.1, ENERGY STAR, January 2008.

[908] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[909] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 2.1, ENERGY STAR, January 2008.

Product Volume (in cubic feet)	kWhEEdailymax
Vertical Configuration	
Solid Door Cabinets	
$0 < V < 15$	$\leq 0.250V + 1.250$
$15 \leq V < 30$	$\leq 0.400V - 1.000$
$30 \leq V < 50$	$\leq 0.163V + 6.125$
$50 \leq V$	$\leq 0.158V + 6.333$
Glass Door Cabinets	
$0 < V < 15$	$\leq 0.607V + 0.893$
$15 \leq V < 30$	$\leq 0.733V - 1.000$
$30 \leq V < 50$	$\leq 0.250V + 13.500$
$50 \leq V$	$\leq 0.450V + 3.500$
Chest Configuration	
Solid or Glass Door Cabinets	$\leq 0.270V + 0.130$

Where V = Association of Home Appliances Manufacturers (AHAM) volume

Illustrative examples – do not use as default assumption

For example, for a 50 ft^2 vertical configuration, solid door freezer:

$$\Delta kWh = ((0.4 * 50 + 1.38) - (0.158 * 50 + 6.333)) * 365$$

$$= 2{,}608.7 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh/HOURS) \times CF$$

Where:

HOURS = *Full load hours*
= *5858* [910]

CF = *Summer Peak Coincidence Factor for measure*
= *0.772* [911]

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[910] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[911] 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.

Illustrative examples – do not use as default assumption

For example, for a 50 ft^2 vertical configuration, solid door freezer:

$$\Delta kW = (2{,}608.7 / 5858) * 0.772$$

$$= 0.34 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [912]

The incremental cost for this measure is assumed to be $25 for solid door freezers and $256 for glass door freezers.

Measure Life

The measure life is assumed to be 12 years.[913]

Operation and Maintenance Impacts

n/a

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[912] Unit Energy Savings (UES) Measures and Supporting Documentation, ComFreezer_v3_0.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum

[913] 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 2.1 requirements[914].

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) * 365$$

Where:

kWhBASEdailymax [915] = *See table below.*

Product Volume (in cubic feet)	kWhBASEdailymax
Solid Door Cabinets	0.10V + 2.04
Glass Door Cabinets	0.12V + 3.34

Where V = Association of Home Appliances Manufacturers (AHAM) volume

kWhEEdailymax [916] = *See table below.*

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[914] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 2.1, ENERGY STAR, January 2008.

[915] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[916] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 2.1, ENERGY STAR, January 2008.

Product Volume (in cubic feet)	kWhEEdailymax
Vertical Configuration	
Solid Door Cabinets	
$0 < V < 15$	$\leq 0.089V + 1.411$
$15 \leq V < 30$	$\leq 0.037V + 2.200$
$30 \leq V < 50$	$\leq 0.056V + 1.635$
$50 \leq V$	$\leq 0.060V + 1.416$
Glass Door Cabinets	
$0 < V < 15$	$\leq 0.118V + 1.382$
$15 \leq V < 30$	$\leq 0.140V + 1.050$
$30 \leq V < 50$	$\leq 0.088V + 2.625$
$50 \leq V$	$\leq 0.110V + 1.500$
Chest Configuration	
Solid or Glass Door Cabinets	$\leq 0.125V + 0.475$

Where V = Association of Home Appliances Manufacturers (AHAM) volume

Illustrative examples – do not use as default assumption

For example, for a 50 ft^2 vertical configuration, solid door refrigerator:

$$\Delta kWh = ((0.1 * 50 + 2.04) - (0.06 * 50 + 1.416)) * 365$$

$$= 957.8 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh / HOURS) * CF$$

Where:

HOURS = Full load hours
= 5858 [917]
CF = Summer Peak Coincidence Factor for measure
= 0.772 [918]

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[917] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[918] 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.

Illustrative examples – do not use as default assumption

For example, for a 50 ft^2 vertical configuration, solid door refrigerator:

$$\Delta kW = (957.8 / 5858) * 0.772$$

$$= 0.13 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [919]

The incremental cost for this measure is assumed to be $0 for solid door refrigerators and $158 for glass door refrigerators.

Measure Life

The measure life is assumed to be 12 years.[920]

Operation and Maintenance Impacts

n/a

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[919] Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigerator_v3.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum.

[920] 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_TOS_NTCOV_0615
Effective Date: June 2015
End Date: TBD

Measure Description

By covering refrigerated cases, the heat gain due to the spilling of refrigerated air and convective mixing with room air is reduced at the case opening. Continuous curtains can be pulled down overnight while the store is closed, yielding significant energy savings.

Definition of Baseline Condition

In order for this characterization to apply, the baseline equipment is assumed to be a refrigerated case without a night cover.

Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be a refrigerated case with a continuous cover deployed during overnight periods. Characterization assumes covers are deployed for six hours daily.

Annual Energy Savings Algorithm

$$\Delta kWh = (LOAD / 12{,}000) * FEET * (3.516) / COP * ESF * 8{,}760$$

$$\Delta kWh = 346.5 * FEET / COP$$

Where:

LOAD = average refrigeration load per linear foot of refrigerated case without night covers deployed
= 1,500 Btu/h[921] *per linear foot*
FEET = linear (horzontal) feet of covered refrigerated case
12,000 = conversion factor - Btu per ton cooling.
3.516 = conversion factor – Coefficient of Performance (COP) to kW per ton.
COP = Coefficient of Performance of the refrigerated case.

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[921] Davis Energy Group, Analysis of Standard Options for Open Case Refrigerators and Freezers, May 11, 2004. Accessed on 7/7/10 < http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Open_Case_Refrig.pdf>

= assume 2.2[922]*, if actual value is unknown.*

ESF = Energy Savings Factor; reflects the percent reduction in refrigeration load due to the deployment of night covers.

= 9%[923]

8,760 = assumed annual operating hours of the refrigerated case

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0$$[924]

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost for this measure is $42 per linear foot of cover installed including material and labor.[925]

Measure Life

The expected measure life is assumed to be 5 years [926].

Operation and Maintenance Impacts

n/a

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[922] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.

[923] 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.

[924] Assumed that the continuous covers are deployed at night; therefore no demand savings occur during the peak period.

[925] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Cost Values and Summary Documentation", California Public Utilities Commission, December 16, 2008 <http://deeresources.com/deer0911planning/downloads/DEER2008_Costs_ValuesAndDocumentation_080530Rev1.zip>

[926] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

Anti-Sweat Heater Controls**

Unique Measure Code(s): CI_RF_TOS_ASHC_0615
Effective Date: June 2015
End Date: TBD

Measure Description

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 that achieve “on-off” control of door heaters based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

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 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 humidity or conductivity control.

Annual Energy Savings Algorithm

$$\Delta kWh = kWbase * NUMdoors * ESF * BF * HOURS$$

Where:

kWbase[927] = *connected load kW for typical reach-in refrigerator or freezer door and frame with a heater.*

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[927] A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different sources for this factor. Connecticut requires site-specific information, whereas New York’s characterization does not explicitly identify the kWbase. Connecticut and Vermont provide values that are very consistent, and the simple average of these two values has been used for the purposes of this characterization.

= If actual kWbase is unknown, assume 0.195 kW for freezers and 0.092 kW for coolers.

NUMdoors = number of reach-in refrigerator or freezer doors controlled by sensor

= Actual number of doors controlled by sensor

ESF[928] *= Energy Savings Factor; represents the percentage of hours annually that the door heater is powered off due to the controls.*

= assume 55% for humidity-based controls, 70% for conductivity-based controls

BF[929] *= Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the increase in cooling load in the building space to cool the additional heat generated by the door heaters.*

= assume 1.36 for low-temp, 1.22 for medium-temp, and 1.15 for high-temp applications

HOURS = Hours of operation

= 8760

Summer Coincident Peak kW Savings Algorithm

ΔkW[930] = 0

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental capital cost is $995 for a door heater controller, $124 for a cooler door, and $219 for a freezer door[931].Values include labor costs.

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[928] A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different estimates of ESF. Vermont is the only TRM that provides savings estimates dependent on the control type. Additionally, these estimates are the most conservative of all TRMs reviewed. These values have been adopted for the purposes of this characterization.

[929] Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, February, 19, 2010

[930] Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings from door heater controls.

[931] Navigant. 2015. *Incremental Cost Study Phase Four, Draft Report*. Burlington, MA.

Measure Life

The expected measure life is assumed to be 12 years. [932]

Operation and Maintenance Impacts

n/a

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[932] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

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 [933]
kBtu_req (School) = Required annual heating output of school (kBtu)
= 22,191 [934]

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[933] 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.

[934] Assumes an elementary school with 300 students; According to 2003 ASHRAE Handbook: HVAC Applications, Elementary School typically uses 0.6 gal/person per day of operation.
Assumes 37 weeks of operation.
Assumes an 80F temperature rise based on a typical hot water holding tank temperature setpoint of 140F and 60F supply water. Actual supply water temperature will vary by season and source.
Water heating requirement equation adopted from FEMP Federal Technology Alert: Commercial Heat Pump Water Heater, 2000.

3.413 = *Conversion factor from kBtu to kWh*

EFee = *Energy Factor of Heat Pump domestic water heater*
= *2.0* [935]

EFbase = *Energy Factor of baseline domestic water heater*
= *0.904* [936]

ΔkWh Office = (6,059 / 3.413) * ((1/0.904) – (1/2.0))
= 1076.2 kWh

ΔkWh School = (22,191 / 3.413) * ((1/0.904) – (1/2.0))
= 3941.4 kWh

If the deemed "kBtu_req" estimates are not applicable, the following equation can be used to estimate annual water heating energy requirements:

$$kBtu\_req = GPD * 8.33 * 1.0 * WaterTempRise * 365$$

Where:

GDP = *Average daily hot water requirements (gallons/day)*
= *Actual usage (Note: days when the building is unoccupied must be included in the averaging calculation)*

8.33 = *Density of water (lb/gallon)*

1.0 = *Specific heat of water (Btu/lb-°F)*

WaterTempRise = *Difference between average temperature of water delivered to site and water heater setpoint (°F)*

365 = *Days per year*

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh / Hours * CF

Where:

Hours (Office) = *Run hours in office*

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[935] 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

[936] Ibid.

= *5885* [937]

Hours (School) = *Run hours in school*

= *2218* [938]

CF (Office) = *Summer Peak Coincidence Factor for office measure*

= *0.630* [939]

CF (School) = *Summer Peak Coincidence Factor for school measure*

= *0.580* [940]

ΔkW Office = (1076.2 / 5885) * 0.630

= 0.12 kW

ΔkW School = (3941.4 / 3.413) * 0.580

= 1.03 kW

If annual operating hours and CF estimates are unknown, use deemed HOURS and CF estimates above. Otherwise, use site specific values.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $925.[941]

Measure Life

The measure life is assumed to be 10 years.[942]

Operation and Maintenance Impacts

n/a

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

[938] Ibid.

[939] Ibid.

[940] Ibid.

[941] Cost 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

[942] 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_TOS_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 a spray valve with a flow rate of 3 gallons per minute.

Definition of Efficient Condition

The efficient equipment is assumed to be a pre-rinse spray valve with a flow rate of 1.6 gallons per minute, and with a cleanability performance of 26 seconds per plate or less.

Annual Energy Savings Algorithm

$$\Delta kWh = \Delta Water \times HOT\% \times 8.33 \times (\Delta T) \times (1/EFF) / 3413$$

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%*[943]

8.33 = *The energy content of heated water (Btu/gallon/°F)*

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[943] 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[944]
EFF = Water heater thermal efficiency
= 0.97[945]
3413 = Factor to convert Btu to kwh

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0$$

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = \Delta Water \times HOT\% \times 8.33 \times (\Delta T) \times (1/EFF) \times 10^{-6}$$

Where:

EFF = Water heater thermal efficiency
= 0.80[946]
10^{-6} = Factor to convert Btu to MMBtu

Annual Water Savings Algorithm

$$\Delta Water = (FLO_{base} - FLO_{eff}) \times 60 \times HOURS_{day} \times 365$$

Where:

$\Delta Water$ = Annual water savings (gal)
FLO_{base} = The flow rate of the baseline spray nozzle
= 3 gallons per minute
FLO_{eff} = The flow rate of the efficient equipment
= 1.6 gallons per minute
60 = minutes per hour
365 = days per year
HOURS = Hours used per day - depends on facility type as below:[947]

Facility Type	Hours of Pre-Rinse Spray Valve Use per

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[944] Engineering judgment; assumes typical supply water temperature of 70°F and a hot water storage tank temperature of 140°F.

[945] Federal Standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/51

[946] IECC 2006. Performance requirement for electric resistance water heaters.

[947] Hours estimates based on *PG&E savings estimates, algorithms, sources* (2005). Food Service Pre-Rinse Spray Valves

	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.[948]

Operation and Maintenance Impacts

n/a

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[948] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

Plug Load End Use

Advanced Power Strip

Unique Measure Code: CI_PL_TOS_APS_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of a Current-Sensing Master/Controlled Advanced Power Strip (APS)in place of a standard “power strip,” a device used to expand a single wall outlet into multiple outlets. This measure is assumed to be a time of sale installation.

Definition of Baseline Condition

The baseline condition is a standard “power strip”. This strip is simply a “plug multiplier” that allows the user to plug in multiple devices using a single wall outlet. Additionally, the baseline unit has no ability to control power flow to the connected devices.

Definition of Efficient Condition

The efficient condition is a Current-Sensing Master/Controlled Advanced Power Strip that functions as both a “plug multiplier” and also as a plug load controller. The efficient unit has the ability to essentially disconnect controlled devices from wall power when the APS detects that a controlling device, or master load, has been switched off. The efficient device effectively eliminates standby power consumption for all controlled devices[949] when the master load is not in use.

Annual Energy Savings Algorithm

ΔkWh = 26.9 kWh[950]

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[949] 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.

[950] 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)

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be \$16 for a 5-plug \$26 for a 7-plug[951].

Measure Life

The measure life is assumed to be 4 years[952].

Operation and Maintenance Impacts

n/a

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acknowledging that investigations of APS savings in other jurisdictions have found significantly higher savings. For example, Northwest Power and Conservation Council, Regional Technical Forum. 2011. “Smart Power Strip Energy Savings Evaluation” found average savings of 145 kWh.

[951] NYSERDA Measure Characterization for Advanced Power Strips

[952] 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_0615
Effective Date: June 2015
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. Fryers that have earned the ENERGY STAR are up to 30% more efficient than standard models. Energy savings estimates are based on a 14" fryer. 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% or gas fryer with heavy load efficiency of 35%.

Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified electric or gas fryer.[953]

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:[954]

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[953] US EPA. April 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Version 2.0

[954] 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>

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.*

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.*

Electric Fryer Performance Metrics: Baseline and Efficient Values

Parameter	Baseline Model	Energy Efficient Model
IDLE (kW)	1.05	1.00
EFF	75%	80%
PC	65	70

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = [\Delta kWh / (HOURS_{DAY} \times DAYS)] \times CF$

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *1.0*[955]

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:[956]

$MMBtu\_Cooking_i$ = *daily cooking energy consumption (MMBtu)*
$MMBtu\_Idle_i$ = *daily idle energy consumption (MMBtu)*
$MMBtu_{base}$ = *the annual energy usage of the baseline equipment calculated using baseline values*
$MMBtu_{eff}$ = *the annual energy usage of the efficient equipment calculated using efficient values*
E_{FOOD} = *ASTM Energy to Food (MMBtu/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.00057*
IDLE = *Idle energy rate (MMBtu/h)*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

Gas Fryer Performance Metrics: Baseline and Efficient Values

Parameter	Baseline Model	Energy Efficient Model

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[955] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of additional data, the characterization assumes the total energy savings divided by the total annual hours of operation and applies a coincidence factor of 1.0. This presumably results in a conservatively low estimate of summer coincident peak savings.

[956] 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>

IDLE (MMBtu/h)	0.014	0.009
EFF	35%	50%
PC	60	65

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost is assumed to be $210[957] for electric fryers and $2,581[958] for gas fryers.

Measure Life

12 years[959]

Operation and Maintenance Impacts

n/a

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[957] 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>

[958] Navigant. 2015. *Incremental Cost Study Phase Four, Draft Report*. Burlington, MA.

[959] 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>

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.[960]

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: [961]

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[960] US EPA. August 2003. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers Eligibility Criteria Version 1.2

[961] 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>

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/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 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.

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

$$\Delta kW = [\Delta kWh / (HOURS_{DAY} \times DAYS)] \times CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*

= *1.0*[962]

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: [963]

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[962] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of additional data, the characterization assumes the total energy savings divided by the total annual hours of operation and applies a coincidence factor of 1.0. This presumably results in a conservatively low estimate of summer coincident peak savings.

[963] 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>

$MMBtu_{base}$ = 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

ΔWater = (GPH_{base} – GPH_{eff}) x $HOURS_{DAY}$ x DAYS

Where: [964]

GPH_{base} = Water consumption rate (gal/h) of baseline equipment
= if water consumption rate of baseline equipment is unknown, assume default values from table below.

GPH_{eff} = Water consumption rate (gal/h) of efficient equipment

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[964] 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>

= *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 Cost[965]

The incremental cost of an 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 gas ENERGY STAR steam cooker is $260 for 3-pans, N/A for 4-pans, $0 for 5-pans, and $870 for 6-pans+.

Measure Life

12 years[966]

Operation and Maintenance Impacts

n/a

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[965] 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>

[966] 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.[967]

Annual Energy Savings Algorithm

$$\Delta kWh = (IDLE_{base} - IDLE_{eff}) / 1000 \times HOURS_{DAY} \times DAYS$$

Where:[968]

$IDLE_{base}$ = *the idle energy rate of the baseline equipment (W). See table below for calculation of default values.*

$IDLE_{eff}$ = *the idle energy rate of the efficient equipment (W). If actual efficient values are unknown, assume default values from table below.*

1,000 = *conversion of W to kW*

$HOURS_{DAY}$ = *average daily operating hours*

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[967] US EPA. April 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0.

[968] 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>

= *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

$$\Delta kW = (IDLE_{base} - IDLE_{eff}) / 1000 \times CF$$

Where:

CF = *Summer Peak Coincidence Factor*

= *1.0*[969]

Hot Food Holding Cabinet Performance Metrics: Baseline and Efficient Values

VOLUME (Cubic Feet)	Product Idle Energy Consumption Rate (Watts)	
	Baseline Model ($IDLE_{base}$)	Efficient Model ($IDLE_{eff}$)
0 < VOLUME < 13	40 x VOLUME	21.5 x VOLUME
13 ≤ VOLUME < 28	40 x VOLUME	2.0 x VOLUME + 254.0
28 ≤ VOLUME	40 x VOLUME	3.8 x VOLUME + 203.5

Note: VOLUME = the internal volume of the holding cabinet (ft^3).
= actual volume of installed unit

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for ENERGY STAR hot food holding cabinets is assumed to be $0.[970]

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[969] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of additional data, the characterization assumes the total energy savings divided by the total annual hours of operation and applies a coincidence factor of 1.0. This presumably results in a conservatively low estimate of summer coincident peak savings.

[970] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

Measure Life

12 years[971]

Operation and Maintenance Impacts

n/a

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[971] 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.[972]

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:[973]

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[972] US EPA. January 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles Eligibility Criteria Version 1.2.

[973] 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>

i = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.
$kWh\_Cooking_i$ = daily cooking energy consumption (kWh)
kWh_Idle_i = daily idle energy consumption (kWh)
kWh_{base} = the annual energy usage of the baseline equipment calculated using baseline values
kWh_{eff} = the annual energy usage of the efficient equipment calculated using efficient values
LB = Pounds of food cooked per day (lb/day)
= if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.
E_{FOOD} = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food
= 0.139
EFF = Heavy load cooking energy efficiency (%)
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
IDLE = Idle energy rate (kW/ft^2)
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
SIZE = size of the griddle surface (ft^2)
$HOURS_{DAY}$ = average daily operating hours
= if average daily operating hours are unknown, assume default of 12 hours/day.
PC = Production capacity ($lb/hr/ft^2$)
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.
DAYS = annual days of operation
= if annual days of operation are unknown, assume default of 365 days.

Efficient Griddle Performance Metrics: Baseline and Efficient Values

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

$$\Delta kW = [\Delta kWh / (HOURS_{DAY} \times DAYS)] \times CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *1.0*[974]

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:[975]

$MMBtu\_Cooking_i$ = *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*
IDLE = *Idle energy rate* ($MMBtu/h/ft^2$)
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

Gas Griddle Performance Metrics: Baseline and Efficient Values

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[974] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of additional data, the characterization assumes the total energy savings divided by the total annual hours of operation and applies a coincidence factor of 1.0. This presumably results in a conservatively low estimate of summer coincident peak savings.

[975] 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 (MMBtu/h/ft^2)	0.00350	0.00265
EFF	32%	38%
PC	4.17	7.50

Annual Water Savings Algorithm

n/a

Incremental Cost[976]

The incremental cost of an electric ENERGY STAR griddle is assumed to be $0. The incremental cost of a gas ENERGY STAR griddle is assumed to be $360.

Measure Life

12 years[977]

Operation and Maintenance Impacts

n/a

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[976] 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>

[977] 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.[978]

Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where: [979]

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[978] US EPA. January 2014. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.1

[979] 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>

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.

Electric Convection Oven Performance Metrics: Baseline and Efficient Values[980]

Parameter	Half Size		Full Size	
	Baseline Model	Energy Efficient Model	Baseline Model	Energy Efficient Model

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[980] Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php

IDLE (kW)	1.03	1.00	2.00	1.60
EFF	68%	71%	65%	71%
PC	45	50	90	90

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = [\Delta kWh / (HOURS_{DAY} \times DAYS)] \times CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *1.0*[981]

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:[982]

$MMBtu\_Cooking_i$ = *daily cooking energy consumption (MMBtu)*
$MMBtu\_Idle_i$ = *daily idle energy consumption (MMBtu)*
$MMBtu_{base}$ = *the annual energy usage of the baseline equipment calculated using baseline values*
$MMBtu_{eff}$ = *the annual energy usage of the efficient equipment calculated using efficient values*
E_{FOOD} = *ASTM Energy to Food (MMBtu/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.000250*
IDLE = *Idle energy rate (MMBtu/h)*

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[981] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of additional data, the characterization assumes the total energy savings divided by the total annual hours of operation and applies a coincidence factor of 1.0. This presumably results in a conservatively low estimate of summer coincident peak savings.

[982] 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>

= *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 is assumed to be $0[983] for electric commercial convection ovens and -$1,778[984] for gas ovens.

Measure Life

12 years[985]

Operation and Maintenance Impacts

n/a

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[983] 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>

[984] Navigant. 2015. *Incremental Cost Study Phase Four, Draft Report*. Burlington, MA.

[985] 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>

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.[986]

Annual Energy Savings Algorithm

$$kWh_{i,j} = (kWh\_Cooking_{i,j} + kWh\_Idle_{i,j}) \times DAYS$$

$$kWh\_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$$
$$kWh\_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j}) \times PCT_j$$

$$kWh_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$kWh_{base} = kWh_{base,conv} + kWh_{base,steam}$$
$$kWh_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

Where:[987]

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[986] US EPA. January 2014. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.1

[987] 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>

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.*

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.

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = [\Delta kWh / (HOURS_{DAY} \times DAYS)] \times CF$$

Where:

CF = Summer Peak Coincidence Factor for measure
= 1.0[988]

Annual Fossil Fuel Savings

$$MMBtu_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_{i)}] \times DAYS$$

$$MMBtu\_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$$
$$MMBtu\_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j}) \times PCT_j$$

$$MMBtu_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} - LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$MMBtu_{base} = kWh_{base,conv} + kWh_{base,steam}$$
$$MMBtu_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

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[988] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of additional data, the characterization assumes the total energy savings divided by the total annual hours of operation and applies a coincidence factor of 1.0. This presumably results in a conservatively low estimate of summer coincident peak savings.

ΔMMBtu = $MMBtu_{base}$ - $MMBtu_{eff}$

Where:[989]

$MMBtu\_Cooking_i$ = daily cooking energy consumption (MMBtu)

$MMBtu\_Idle_i$ = daily idle energy consumption (MMBtu)

$MMBtu_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values

$MMBtu_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values

$E_{FOOD,conv}$ = ASTM Energy to Food (MMBtu/lb); the amount of energy absorbed by the food during convention mode cooking, per pound of food
= 0.000250

$E_{FOOD,steam}$ = ASTM Energy to Food (MMBtu/lb); the amount of energy absorbed by the food during steam mode cooking, per pound of food
= 0.000105

LB = Pounds of food cooked per day (lb/day)
= if average pounds of food cooked per day is unknown, assume default of 250 lbs/day.

IDLE = Idle energy rate (MMBtu/h)
= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.

Gas Combination Oven Performance Metrics: Baseline and Efficient Values

Parameter	No. of Pans	Baseline Model		Energy Efficient Model	
		Convection Mode	Steam Mode	Convection Mode	Steam Mode
IDLE (MMBtu/h)	< 15	0.008747	0.018656	0.000150 x PANS + 0.005425	0.000200 x PANS + 0.006511
	>= 15 and < 30	0.007823	0.024562		
	>= 30	0.013000	0.043300		
EFF	All	52%	39%	56%	41%
PC	< 15	125	195	124	172

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[989] 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	No. of Pans	Baseline Model		Energy Efficient Model	
		Convection Mode	Steam Mode	Convection Mode	Steam Mode
	>= 15 and < 30	176	211	210	277
	>= 30	392	579	394	640

Note: PANS = The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for commercial combination ovens is assumed to be \$0[990]

Measure Life

12 years[991]

Operation and Maintenance Impacts

n/a

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[990] 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>

[991] Ibid.

APPENDIX

A. Supporting Calculation Work Sheets

For each of the embedded excel work sheets below, double click to open the file and review the calculations.

1. MidAtlantic Lighting Adjustments and O&M.xls – this contains 6 tabs; the first details the ISR and Measure Life adjustments, the second the CFL delta watts multiplier calculations, and the remaining tabs show the Operation and Maintenance calculations for RES CFL, RES Interior Fixture, RES Exterior Fixtures and C&I CFL.

B. Recommendation for Process and Schedule for Maintenance and Update of TRM Contents

C. Description of Unique Measure Codes

D. Commercial & Industrial Lighting Operating Hours, Coincidence Factors, and Waste Heat Factors

A. Supporting Calculation Work Sheets

Residential Lighting Markdown Impact Evaluation (2009) (CT, MA, RI, VT)

Table 5–21: Calculation of First-Year and Lifetime Installation Rates p59

Measure	Markdown	Measure Life	Both
Total number of products	1,202	168	1,370
Number of products ever installed[a]	921	129	1,050
First-year installation rate	**76.60%**	**76.80%**	**76.60%**
Number of products likely to be installed in future[b]	250	37	287
Lifetime number of products to be installed[c]	1,171	166	1,337
Lifetime installation rate	**97.40%**	**99.10%**	**97.60%**

Initial Install Rate (From Empower Study)	0.88
Lifetime Install Rate (from 2009 RLW study)	0.97
Therefore 'future install'	0.09
initial product life (based on Jump et al report)	5.2 yrs

Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs
Table 6-7: Reasons for Not Installing Products Purchased through the RLP (p67)

% of future installs to replace CFLs (bought as spares)	57%
% of future installs to replace incandescents	43%

B. Recommendation for Process and Schedule for Maintenance and Update of TRM Contents

Once developed, the Mid-Atlantic TRM will benefit from an objective and thoughtful update process. Defining a process that coordinates with the needs of users, evaluators, and regulators is critical. Below we outline our preliminary proposal for a process for the update of information and recommendations on the coordination of the timing of this process with other critical activities.

Proposed TRM Update Process

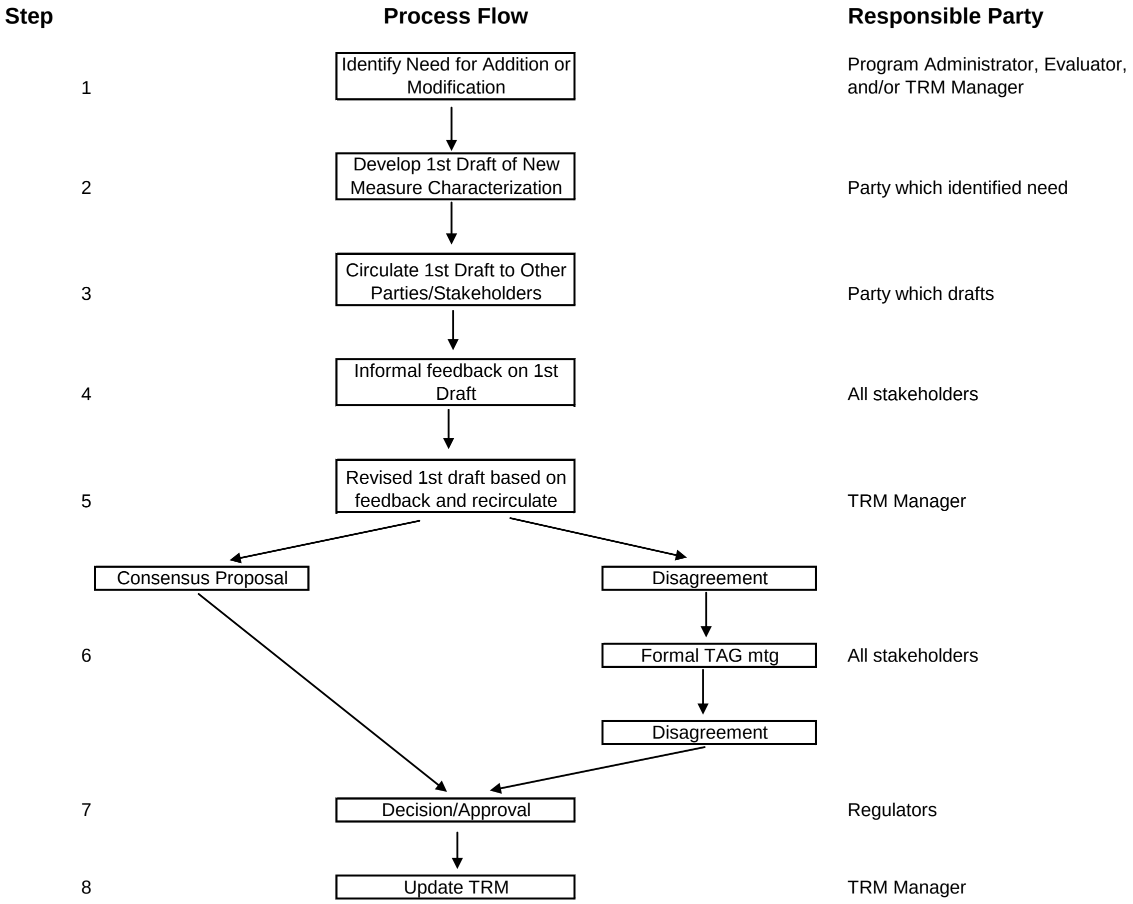
Once a TRM has been developed, it is vital that it is kept up to date, amended, and maintained in a timely and effective manner. There are three main points in time when a TRM is most likely to require changes:

1. New measure additions – As new technologies become cost effective, they will need to be characterized and added to the manual.
2. Existing measure updates – Updates will be required for a number of reasons. Examples include: the federal standard for efficiency of a measure is increased; the qualification criteria are altered; the measure cost falls; or a new evaluation provides a better value of an assumption for a variable. In such cases, the changes must be flagged and appropriate changes made to the TRM.
3. Retiring existing measures – When the economics of a measure become such that it is no longer cost effective, or the free rider rate is so high that it is not worth supporting, the measure should be retired.

It is important to maintain a record of changes made to the TRMs over time. It is therefore recommended to establish and maintain a Master Manual, containing all versions of each TRM in chronological order, and an abridged User Manual, in which only the current versions of active measures are included. Archived older information can be made available on a website or other accessible location.

The flowchart presented below outlines steps that will result in effective review and quality control for TRM updates.

TRM Update Process Flow Chart



Key Roles and Responsibilities

This process requires a number of different roles to ensure effectiveness, sufficient review, and independence. The specific parties who will hold these roles in the Mid-Atlantic TRM maintenance context will need to be identified by jurisdiction. The following list of key responsibilities is given as a starting place:

- Program administrators (utilities, MEA, SEU)
  - Identifies need for new or revised measure characterization (usually due to program changes or program/market feedback)
  - Researches and develops 1st draft measure characterizations when it identifies need

  - Develops 2nd draft measure characterizations following feedback on 1st draft from all parties
  - Feedback on draft measure characterizations from other parties
  - Participant in Technical Advisory Group (TAG) for formal discussion and dispute resolution when needed
  - Input to regulators if TAG process does not resolve all issues
- Independent TRM Manager (consultant or mutually agreed upon nominee)
  - Identifies need for revised measure characterization (usually based on knowledge of local or other relevant evaluation studies)
  - Researches and develops 1st draft measure characterizations when it identifies need
  - Feedback on 1st draft measure characterizations from other parties
  - Develops 2nd draft measure characterizations following feedback on 1st draft from all parties
  - Leads Technical Advisory Group (TAG) for formal discussion and dispute resolution when needed
  - Input to regulators if TAG process does not resolve all issues
  - Manages and updates TRM manuals
- Evaluators
  - Identifies need for revised measure characterization (usually based on local evaluation studies it has conducted or managed)
  - Input on draft measure characterizations developed by other parties
  - Participates in TAG meetings when appropriate
  - Performs program evaluation - includes statewide market assessment and baseline studies, savings impact studies (to measure the change in energy and / or demand use attributed to energy efficiency), and other energy efficiency program evaluation activities
  - Verifies annual energy and capacity savings claims of each program and portfolio
- Regulators/Commission staff
  - May serve as ultimate decision maker in any unresolved disputes between implementers, evaluators, and TRM Manager

Note that the process and responsibilities outlined above assume that the manager of the TRM is an entity independent from the program administrators. This is the approach the state of Ohio has recently adopted, with the Public Utilities Commission hiring a contractor to serve that function. Alternatively, the TRM could be managed by the Program Administrators themselves. That approach can also work very well as long as there is an independent party responsible for (1) reviewing and (2) either agreeing with proposed additions/changes or challenging such changes – with the regulators having final say regarding any disputes.

The process outlined above also assumes that there are several potential stages of "give and take" on draft modifications to the TRM. At a minimum, there is at least one round of informal feedback and comment between the program administrators and the independent reviewer (TRM manager or otherwise). Other parties could be invited to participate in this process as well. In the event that such informal discussions do not resolve all issues, the participants may find it beneficial to establish a Technical Advisory Group (TAG) to provide a more formal venue for resolution of technical disputes prior to any submission to the regulators. This group would include representation from the program administrators, the evaluators (when deemed useful), the TRM Manager, and Commission staff. The mission of such a group would be to discuss and reach agreement on any unresolved issues stemming from new measure proposals, savings verifications, or evaluations. They could also review and comment on the methodology and associated assumptions underlying measure savings calculations and provide an additional channel for transparency of information about the TRM and the savings assessment process.

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. An example of the timeline established from such a coordinated process is given below.

In this example, it assumed that updates to the TRM occur only in the second half of the year. One option is to establish two specific update deadlines: one at the end of August and the other at the end of December. The first would ensure that the best available data are available for utility planning for the following year. The second would ensure that best available assumptions are in place prior to the start of the new program year. The rationale for not updating the TRM during the first half of the year is that time is usually devoted, in part, to documenting, verifying and approving savings claims from the previous year. For example, the program administrator will likely require two months to produce its annual savings claim for the previous year. An independent reviewer will then require two to three months to review and probe that claim, with considerable back and forth between the two parties being very common. Typically, final savings estimates for the previous year are not finalized and approved until June.

Needless to say, the definitive schedule for savings verification and TRM updating will need to be developed with considerable input from state regulators. This plan and timeline will be also informed by each region's Independent Program Evaluator and the EM&V plans they propose.

Annual Verification and TRM Update Timeline (example)

<table>
<tr><th></th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td rowspan="2">Utility</td><td colspan="2">Draft annual savings report</td><td colspan="3">No TRM submittal during SV</td><td></td><td colspan="6">Draft new or updated TRMs developed and submitted to TRM Manager, participate in TAG</td></tr>
<tr><td colspan="3"></td><td colspan="2">SV Response</td><td>Prior year data finalized</td><td colspan="6" rowspan="2">Technical Advisory Group (TAG) negotiations and evaluation</td></tr>
<tr><td rowspan="2">Evaluator</td><td colspan="2"></td><td colspan="3">Savings Verification (SV)</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="3">No TRM review during SV</td><td></td><td colspan="6">Refers need for TRM updates to TRM Manager, provides input on TRMs</td></tr>
<tr><td>TRM Manager/ Implementation staff</td><td colspan="2"></td><td colspan="2"></td><td colspan="2">Make final savings determination</td><td colspan="6">Draft new or updated TRMs developed, Review drafts provided by utilities, participate in TAG, propose new or updated TRMs</td></tr>
</table>

C. 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
RTR	Retrofit
ERT	Early Retirement
INS	Direct Install
MEASURE	
CFLSCR	Compact Fluorescent Screw-In
CFLFIN	Compact Fluorescent Fixture, Interior
CFLFEX	Compact Fluorescent Fixture, Exterior
REFRIG	Refrigerator
FANMTR	Furnace Fan Motor
RA/CES	Window Air Conditioner Energy Star
RA/CT1	Window Air Conditioner Tier 1
CENA/C	Central Air Conditioner
SHWRHD	Low Flow Showerhead
FAUCET	Low Flow Faucet
HWWRAP	Water Tank Wrap
HPRSHW	Heat Pump Water Heater, Residential

CWASHES	Clothes Washer, Energy Star
CWASHT3	Clothes Washer, Tier 3
WINDOW	Window, Energy Star
HPT8	High Performance T8 Lighting
T5	T5 Lighting
MHFIN	Metal Halide Fixture, Interior
MHFEX	Metal Halide Fixture, Exterior
SODIUM	High Pressure Sodium Lighting
LECEXI	LED Exit Sign
DELAMP	Delamping
OSWALL	Occupancy Sensor, Wall box
UNIA/C	Unitary Air Conditioning system
EMOTOR	Efficient Motor
VFDRIVE	Variable Frequency Drive
FREEZER	Freezer
HPCIHW	Heat Pump Water Heater, Commercial

D. Commercial & Industrial Lighting Operating Hours, Coincidence Factors, and Waste Heat Factors

C&I Interior Lighting Operating Hours by Building Type[992]

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[993]	Large Commercial/Industrial	3,830

Note(s): “Other” building types includes all building types except those listed above.

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[992] 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

[993] Estimated assuming hours from 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 weighted by building type floorspace for the Northeast census region from the Commercial Building Energy Consumption Survey, US Energy Information Administration, 2003.

C&I Interior Lighting Coincidence Factors by Building Type[994]

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[995]
Warehouse/ Industrial	Large Commercial/Industrial	0.7	0.72
	Small Commercial	0.68	0.7
Unknown[996]	Large Commercial/Industrial	0.63	0.62

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) “Other” building types includes all building types except those listed above.

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[994] 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

[995] C&I Lighting Load Shape Project FINAL Report, KEMA, 2011

[996] Estimated assuming coincidence factors from 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 weighted by building type floorspace for the Northeast census region from the Commercial Building Energy Consumption Survey, US Energy Information Administration, 2003.

Waste Heat Factors for C&I Lighting – Known HVAC Types[997]

State, Utility	Building Type	Demand Waste Heat Factor (WHFd)		Annual Energy Waste Heat Factor by Heating Type (WHFe)		
		Utility	PJM	Gas	Electric Resistance	Heat Pump
Maryland, BGE	Office	1.36	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.23	1.24	1.02	0.75	0.89
	Other	1.35	1.33	1.08	0.82	0.93
Maryland, SMECO	Office	1.36	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.23	1.25	1.02	0.75	0.89
	Other	1.35	1.33	1.08	0.82	0.93
Maryland, Pepco	Office	1.36	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.23	1.25	1.02	0.75	0.89
	Other	1.35	1.33	1.08	0.82	0.93
Maryland, DPL	Office	1.35	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.22	1.23	1.02	0.75	0.89
	Other	1.34	1.32	1.08	0.82	0.93
	Office	1.34	1.31	1.10	0.85	0.94

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[997] 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.

State, Utility	Building Type	Demand Waste Heat Factor (WHFd)		Annual Energy Waste Heat Factor by Heating Type (WHFe)		
		Utility	PJM	Gas	Electric Resistance	Heat Pump
Maryland, Potomac Edison	Retail	1.27	1.25	1.06	0.83	0.95
	School	1.45	1.45	1.10	0.81	0.96
	Warehouse	1.2	1.21	1.02	0.75	0.89
	Other	1.33	1.31	1.08	0.82	0.93
Washington, D.C., All	Office	1.36	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.23	1.25	1.02	0.75	0.89
	Other	1.35	1.33	1.08	0.82	0.93
Delaware, All	Office	1.35	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.22	1.23	1.02	0.75	0.89
	Other	1.34	1.32	1.08	0.82	0.93

Note(s): “Other” building types includes all building types except those listed above.

Waste Heat Factors for C&I Lighting – Unknown HVAC Types[998]

Utility	Building Type	Demand Waste Heat Factor – Unknown AC (WHFd)			Annual Energy Waste Heat Factor – Unknown Heating Type (WHFe)	
		Utility	PJM	No AC	Unknown	Unconditioned
	Office	1.31	1.28	1.00	0.99	1.00

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[998] 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.

Utility	Building Type	Demand Waste Heat Factor - Unknown AC (WHFd)			Annual Energy Waste Heat Factor - Unknown Heating Type (WHFe)	
		Utility	PJM	No AC	Unknown	Unconditioned
Maryland, BGE	Retail	1.25	1.24	1.00	0.99	1.00
	School	1.38	1.38	1.00	1.07	1.00
	Warehouse	1.13	1.14	1.00	0.99	1.00
	Other	1.25	1.24	1.00	1.04	1.00
Maryland, SMECO	Office	1.31	1.28	1.00	0.99	1.00
	Retail	1.25	1.24	1.00	0.99	1.00
	School	1.38	1.38	1.00	1.07	1.00
	Warehouse	1.13	1.14	1.00	0.99	1.00
	Other	1.26	1.24	1.00	1.04	1.00
Maryland, Pepco	Office	1.31	1.28	1.00	0.99	1.00
	Retail	1.25	1.24	1.00	0.99	1.00
	School	1.38	1.38	1.00	1.07	1.00
	Warehouse	1.13	1.14	1.00	0.99	1.00
	Other	1.26	1.24	1.00	1.04	1.00
Maryland, DPL	Office	1.31	1.28	1.00	0.99	1.00
	Retail	1.25	1.24	1.00	0.99	1.00
	School	1.38	1.38	1.00	1.07	1.00
	Warehouse	1.13	1.13	1.00	0.99	1.00
	Other	1.25	1.24	1.00	1.04	1.00
Maryland, Potomac Edison	Office	1.3	1.27	1.00	0.99	1.00
	Retail	1.25	1.23	1.00	0.99	1.00
	School	1.39	1.39	1.00	1.07	1.00
	Warehouse	1.12	1.12	1.00	0.99	1.00
	Other	1.23	1.23	1.00	1.04	1.00
	Office	1.31	1.28	1.00	0.99	1.00

Utility	Building Type	Demand Waste Heat Factor - Unknown AC (WHFd)			Annual Energy Waste Heat Factor - Unknown Heating Type (WHFe)	
		Utility	PJM	No AC	Unknown	Unconditioned
Washington, D.C., All	Retail	1.25	1.24	1.00	0.99	1.00
	School	1.38	1.38	1.00	1.07	1.00
	Warehouse	1.13	1.14	1.00	0.99	1.00
	Other	1.26	1.24	1.00	1.04	1.00
Delaware, All	Office	1.31	1.28	1.00	0.99	1.00
	Retail	1.25	1.24	1.00	0.99	1.00
	School	1.38	1.38	1.00	1.07	1.00
	Warehouse	1.13	1.13	1.00	0.99	1.00
	Other	1.25	1.24	1.00	1.04	1.00

Note(s): “Other” building types includes all building types except those listed above.