Northeast Energy Efficiency Partnerships

MID-ATLANTIC
TECHNICAL REFERENCE MANUAL
VERSION 4.0

June 2014

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. http://shelteranalytics.com

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A Project of the Regional Evaluation, Measurement and Verification Forum

June 2014

Prepared by Shelter Analytics

Facilitated and Managed by Northeast Energy Efficiency Partnerships

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PREFACE

The Regional EM&V Forum

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

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.

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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.

Context

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

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

This is the fourth generation (third 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://neep.org/emv-forum/forum-products-and-guidelines. 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.

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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.

Note that the TRM typically provides *example calculations* for measures requiring “actual” values. These are for illustrative purposes only.

- All estimates of savings are annual savings and are assumed to be realized for each year of the measure life (unless otherwise noted).
- Unless otherwise noted, measure life is defined to be “The life of an energy consuming measure, including its equipment life and measure persistence (not savings persistence)” (EMV Forum Glossary). Conceptually it is similar to expected useful life, but the results are not necessarily derived from modeling studies, and many are from a report completed for New England program administrators’ and regulators’ State Program Working Group that is currently used to support the New England Forward Capacity Market M&V plans.
- Where deemed values for savings are provided, these represent average savings that could be expected from the average measures that might be installed in the region during the current program year.
- For measures that are not weather-sensitive, peak savings are estimated whenever possible as the average of savings between 2 pm and 6 pm across all summer weekdays (i.e. PJM’s EE Performance Hours for its Reliability Pricing Model). Where possible for cooling measures, we provide estimates of peak savings in two different ways. The primary way is to estimate peak savings during the most typical peak hour (assumed here to be 5 p.m.) on days during which system peak demand typically occurs (i.e., the hottest summer weekdays). This is most indicative of actual peak benefits. The secondary way – typically provided in a footnote – is to estimate peak savings as it is measured for non-cooling measures: the average between 2 pm and 6 pm across _all_ summer weekdays (regardless of temperature). The second way is presented so that values can be bid into the PJM RPM.
- Wherever possible, savings estimates and other assumptions are based on mid-Atlantic data. 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

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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://neep.org/emv-forum/forum-products-and-guidelines.

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:

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. 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

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[4] They are captured only for lighting measures.

Program	Attributes
	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

RESIDENTIAL MARKET SECTOR

Lighting End Use

General Purpose CFL Screw base, Residential*

Unique Measure Code(s): RS_LT_TOS_CFLSCR_0414

Effective Date: June 2014
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.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

Version 4 of this TRM introduces a new methodology for calculating the delta watts in this lighting measure; lumen equivalence. This requires the user to determine the bulb type, wattage and lumen rating of the efficient bulb and find a baseline bulb with equivalent lumens. Since this methodology requires a

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[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.

change to the information required to be collected for these measures and a potentially burden on utilities, the existing and new methodologies are both provided below. A single methodology should be used for all measures in a particular utility or program to prevent the potential implication of claiming whichever methodology provides higher savings.

Delta Watts Multiplier Method:

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

Where:

CFLwatts = CFL Lamp Watts (if known).

DeltaMultiplier = Multiplier to calculate delta watts. Depends upon bulb wattage and year of replacement[6]*:*

CFL Wattage	Delta Watts Multiplier
	2014 and Beyond
15 or less	1.83
16-20	1.79
21W+	1.84

If Compact Fluorescent Watts is unknown use 25.1[7] *from 2013 onwards as the delta watts (i.e. for (CFLwatts * DeltaMultiplier)).*

See below for remaining variables

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[6] Average wattage of compact fluorescent from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009. Post EISA multipliers are calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014); see MidAtlantic CFL Adjustments.xls. Note from 2014 on all wattages listed are subject to EISA and therefore are a lower delta watts multiplier.

[7] To account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below. Calculated by dividing 45.7W (delta between 61.2W and 15.5W from RLW study referenced above) by the average 2014 "Delta Watts Multiplier" from table.

Lumen Equivalence Method:

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

Where:

WattsBase = Based on lumens of CFL bulb[8]:

Minimum Lumens	Maximum Lumens	$Watts_{Base}$
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	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)	0.92[9]
Direct Install	0.88[10]

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[8] Base wattage is based upon the post first phase of EISA wattage.

[9] Starting with a first year ISR of 0.88 (based on EmPOWER Maryland 2011 Evaluation Report; Chapter 5: Lighting and Appliances) 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 0.88 + (0.43*0.09) = 0.92. See MidAtlantic CFL Adjustments.xls for calculation.

[10] Assumption is based on the EmPOWER Maryland 2011 Evaluation Report 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

HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	3.0	1,100[11]
Multi Family Common Areas	16.3	5,950[12]
Exterior	4.5	1,643[13]
Unknown[14]	3.15	1,150

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

	$WHFe_{Cool}$
Building with cooling	1.12[15]
Building without cooling or exterior	1.0
Unknown	1.09[16]

Megdal & Associates, 2003; “2002/2003 Impact Evaluation of LIPA's Clean Energy Initiative REAP Program”, which estimated 81%.

[11] Based on Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Lighting Program.” April 4, 2014, page 56.

[12] 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.

[13] 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

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

[15] 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).

[16] 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).

$WHFe_{Heat}$ = *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[17]

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

= *47%*[18] *for interior or unknown location*

= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*

= *actual. If not available use*[19]*:*

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006	7.7	2.26
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.67[20]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[21]

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

[18] 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.

[19] 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.

[20] 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.

[21] Based on KEMA baseline study for Maryland.

Illustrative examples – do not use as default assumption

Delta Watts Multiplier method:
A 13W CFL bulb purchased in 2014 in unknown location:

$$\Delta kWh = ((13 * 1.83)/1000) * 0.92 * 1100 * (0.894 + (1.09-1))$$

$$= 23.7\ kWh$$

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

$$\Delta kWh = ((43-13)/1000) * 0.92 * 1100 * (0.894 + (1.09-1))$$

$$= 29.9\ kWh$$

Summer Coincident Peak kW Savings Algorithm

Delta Watts Multiplier Method:

$$\Delta kW = ((CFLwatts * DeltaMultiplier) /1000) * ISR * WHFd * CF$$

Lumen Equivalence Method:

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

Where:

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

	WHFd
Building with cooling	*1.24*[22]
Building without	1.0

---

[22] 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).

cooling or exterior	
Unknown	*1.18*[23]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Coincidence Factor CF
Residential interior and in-unit Multi Family	0.09[24]
Multi Family Common Areas	0.43[25]
Exterior	0.018[26]
Unknown	0.09

Illustrative examples – do not use as default assumption
Delta Watts Multiplier Method:
A 13W CFL bulb purchased in 2014:

ΔkW = ((13 * 1.83) / 1000) * 0.92 * 1.18 * 0.09

= 0.0023 kW

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

ΔkW = ((43-13) / 1000) * 0.92 * 1.18 * 0.09

= 0.0029 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 Watts Multiplier Method:

ΔMMBtuPenalty[27] = - ((((CFLwatts * DeltaMultiplier) / 1000) * ISR * Hours

---

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

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

[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.

$$* HF * 0.003412) / \eta Heat) * \%FossilHeat$$

Lumen Equivalence Method:

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

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[28] *for interior or unknown location*
= *0% for exterior or unheated location*
0.003412 =*Converts kWh to MMBtu*
ηHeat = *Efficiency of heating system*
=*72%*[29]
%FossilHeat = *Percentage of home with non-electric heat*

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[30]

Illustrative examples – do not use as default assumption
Delta Watts Multiplier Method:
A 13W CFL bulb purchased in 2014 in an unknown location:

$$\Delta MMBtuPenalty = - (((13 * 1.83)/1000) * 0.92 * 1100 * 0.47 * 0.003412/0.72) * 0.625$$

$$= - 0.036 \text{ MMBtu}$$

---

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

[28] 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.

[29] 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).

[30] Based on KEMA baseline study for Maryland.

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

ΔMMBtuPenalty = - (((43-13)/1000) * 0.92 * 1100 * 0.47 * 0.003412/0.72) * 0.625

= - 0.042 MMBtu

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[31].

For the Direct Install measure, the full cost of $3.20[32] per bulb should be used plus $5 labor[33] 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	5.5[34]
Multi Family Common Areas	1.0[35]

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[31] Based on incremental costs for 60W equivalent (dominant bulb) from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.
[32] Ibid. Based on 15W CFL,
[33] Assumption based on 15 minutes (including portion of travel time) and $20 per hour.
[34] 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.[34]

Exterior	3.7[36]
Unknown	5.5

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 CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Standard Incandescent	Efficient Incandescent
Replacement Cost	$0.50	$1.40[37]
Component Life[38] (years) Residential interior, in-unit Multi Family or unknown	0.91[39]	0.91[40]
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[41]:

Residential interior and in-unit Multi Family

CFL wattage	NPV of

---

[35] Based proportionately on the residential assumption and the differing hours of use (1100/5950 * 5.5 = 1.0).

[36] Ibid. (1100/1643 * 5.5 = 3.7)

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

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

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

[40] 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.

[41] 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 CFL adjustments_032014’ for more information.

	baseline Replacement Costs
	2014 on
21W+	$5.77
16-20W	$5.77
15W and less	$5.77

Multi Family Common Areas

CFL wattage	NPV of baseline Replacement Costs
	2014 on
21W+	$6.02
16-20W	$6.02
15W and less	$6.02

Exterior

CFL wattage	NPV of baseline Replacement Costs
	2014 on
21W+	$6.41
16-20W	$6.41
15W and less	$6.41

Specialty CFLs, Residential*

Unique Measure Code(s): RS_LT_TOS_SPECCFL_0414

Effective Date: June 2014
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[42] 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

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

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[42] 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.

Where:

WattsBase = If actual CFL lumens is known – find the equivalent baseline wattage from the table below[43]*; use 61.7W if unknown*[44]

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals >=2601	2601	2999	150
	3000	5279	200
	5280	6209	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

---

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

[44] 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
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[45]	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[46]	30

WattsEE = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown[47]

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

[46] As above.

[47] An Illinois evaluation (Energy Efficiency / Demand Response Plan: Plan Year 2 (6/1/2009-

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

Program	In Service Rate (ISR)
Time of Sale (Retail)	0.92[48]
Direct Install	0.88[49]

HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential and in-unit Multi Family	3.0	1,100[50]
Multi Family Common Areas	16.3	5,950[51]
Exterior	4.5	1,643[52]

5/31/2010) Evaluation Report: Residential Energy Star ® Lighting http://ilsag.org/yahoo_site_admin/assets/docs/ComEd_Res_Lighting_PY2_Evaluation_Report_2010-12-21_Final.12113928.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).

[48] Starting with a first year ISR of 0.88 (based on EmPOWER Maryland 2011 Evaluation Report; Chapter 5: Lighting and Appliances) 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 0.88 + (0.43*0.09) = 0.92. See MidAtlantic CFL Adjustments.xls for calculation.

[49] Assumption is based on the EmPOWER Maryland 2011 Evaluation Report 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%.

[50] Based on Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Lighting Program." April 4, 2014, page 56.

[51] 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.

[52] 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;

Unknown[53]	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[54]
Building without cooling or exterior	1.0
Unknown	1.09[55]

$WHFe_{Heat}$ = *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[56]

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

= *47%*[57] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*

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http://publicservice.vermont.gov/energy/ee_files/efficiency/eval/marivtfinalresultsmemodelivered.pdf

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

[54] 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).

[55] 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).

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

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

= *actual. If not available use*[58]*:*

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006	7.7	2.26
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.67[59]

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[60]

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) * 0.92 * 1100 * (0.894 + (1.09 – 1))

= 44.8 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*[61]

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[58] 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.

[59] 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.

[60] Based on KEMA baseline study for Maryland.

Building without cooling or exterior	1.0
Unknown	*1.18*[62]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Coincidence Factor CF
Residential interior and in-unit Multi Family	0.09[63]
Multi Family Common Areas	0.43[64]
Exterior	0.018[65]
Unknown	0.09

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

$$\Delta kW = ((60 - 15) / 1000) * 0.92 * 1.18 * 0.09$$

$$= 0.0044 \text{ kW}$$

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]):

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

---

[61] 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).

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

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

[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.

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*
=*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) * 0.92 * 1100 * 0.47 * 0.003412/0.75) * 1.0

= - 0.097 MMBtu

If home heating fuel is unknown:

ΔMMBtuPenalty = - (((60 - 15)/1000) * 0.92 * 1100 * 0.47 * 0.003412/0.72) * 0.625

= - 0.063 MMBtu

---

[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.

[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.

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.

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	1.3[74]
Exterior	4.6[75]
Unknown	6.8

Operation and Maintenance Impacts

Life of the baseline bulb is assumed to be 0.87 year 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 $4.90[77].

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[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.

[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] Based proportionately on the residential assumption and the differing hours of use (1100/5950 * 6.8 = 1.3).

[75] Ibid. (1100/1643 * 6.8 = 4.6)

[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_0414 and RS_LT_INS_CFLIN_0414

Effective Date: June 2014
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.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

Version 4 of this TRM introduces a new methodology for calculating the delta watts in this lighting measure; lumen equivalence. This requires the user to determine the bulb type, wattage and lumen rating of the efficient bulb and find a baseline bulb with equivalent lumens. Since this methodology requires a change to the information required to be collected for these measures and a potentially burden on utilities, the existing and new methodologies are both provided below. A single methodology should be used for all measures in a particular utility or program to prevent the potential implication of claiming whichever methodology provides higher savings.

Delta Watts Multiplier Method:

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

Where:

CFLwatts = CFL Lamp Watts (if known).

DeltaMultiplier = Multiplier to calculate delta watts. Depends upon bulb wattage and year of replacement[78]*:*

CFL Wattage	Delta Watts Multiplier	
	2013	2014 and Beyond
15 or less	2.95	1.83
16-20	1.79	1.79
21W+	1.84	1.84

If Compact Fluorescent Watts is unknown use 30.1[79] *from 2013 onwards as the delta watts (i.e. for (CFLwatts * DeltaMultiplier)).*

See below for remaining variables

Lumen Equivalence Method:

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

Where:

WattsBase = Based on lumens of CFL bulb[80]:

Minimum Lumens	Maximum Lumens	$Watts_{Base}$
5280	6209	300

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[78] Average wattage of compact fluorescent from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009. Post EISA multipliers are calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014); see MidAtlantic CFL Adjustments.xls.

[79] Calculated by multiplying 48.7 by the average adjustment 2014 percentage adjustment from table below. This adjustment should be made in 2013 since this is the midpoint of the 3 EISA adjustment years.

[80] Base wattage is based upon the post first phase of EISA wattage.

3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	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 [81]

HOURS = Average hours of use per year

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	3.0	1,100[82]
Multi Family Common Areas	16.3	5,950[83]
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[84]

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[81] 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).

[82] Based on Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Lighting Program." April 4, 2014, page 56.

[83] 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.

[84] 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

Building without cooling or exterior	1.0
Unknown	1.09[85]

$WHFe_{Heat}$ = *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[86]

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[87] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[88]:

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006	7.7	2.26
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.67[89]

Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP).

[85] 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).

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

[87] 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.

[88] 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.

[89] 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%[90]

Illustrative example – do not use as default assumption
Delta Watts Multiplier method:
A CFL fixture purchased in 2014:

ΔkWh = ((30.1) / 1000) * 0.95 * 1100 * (0.894 + (1.09 – 1))

= 31 kWh

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

ΔkWh = (3 * ((29-11)/1000)) * 0.95 * 1100 * (0.894 + (1.09 – 1))

= 56 kWh

Summer Coincident Peak kW Savings Algorithm

Delta Watts Multiplier Method:

ΔkW = (#lamps * (CFLwatts * DeltaMultiplier /1000)) * ISR * WHFd * CF

Lumen Equivalence Method:

ΔkW = (#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*[91]

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[90] Based on KEMA baseline study for Maryland.

[91] The value is estimated at 1.24 (calculated as 1 + (0.66 / 2.8)). See footnote relating to WHFe

Building without cooling or exterior	1.0
Unknown	*1.18*[92]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Coincidence Factor CF
Residential interior and in-unit Multi Family	0.09[93]
Multi Family Common Areas	0.43[94]
Unknown	0.09

Illustrative example – do not use as default assumption

Delta Watts Multiplier Method:

A CFL fixture purchased in 2014:

ΔkW = (30.1 / 1000) * 0.95 * 1.18 * 0.09

= 0.003 kW

Lumen Equivalence Method:

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

ΔkW = (3 * ((29-11) / 1000)) * 0.92 * 1.18 * 0.09

= 0.0054 kW

Annual Fossil Fuel Savings Algorithm

Heating Penalty if Fossil Fuel heated home (if heating fuel is unknown assume

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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).

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

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

[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'.

62.5% of homes heated with fossil fuel[95]):

Delta Watts Multiplier Method:

$$\Delta MMBtuPenalty^{96} = - ((((\#lamps * (CFLwatts * DeltaMultiplier) / 1000)) * ISR * Hours * HF * 0.003412) / \eta Heat) * \%FossilHeat$$

Lumen Equivalence Method:

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

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%[97] for interior or unknown location*
= *0% for exterior or unheated location*
0.003412 =*Converts kWh to MMBtu*
ηHeat = *Efficiency of heating system*
=*72%[98]*
%FossilHeat = *Percentage of home with non-electric heat*

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[99]

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[95] Based on KEMA baseline study for Maryland.

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

[97] 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.

[98] 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).

[99] Based on KEMA baseline study for Maryland.

Illustrative example – do not use as default assumption

Delta Watts Multiplier Method:
A CFL fixture purchased in 2013 in an unknown location:

$$\Delta MMBtuPenalty = - (((30.1)/1000) * 0.95 * 1100 * 0.47 * 0.003412/0.72) * 0.625$$

$$= - 0.044\ MMBtu$$

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

$$\Delta MMBtuPenalty = - (((3 * (29-11)/1000)) * 0.95 * 1100 * 0.47 * 0.003412/0.72) * 0.625$$

$$= - 0.079\ MMBtu$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an interior fixture is assumed to be $32[100].

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[101] will therefore need to be reduced each year and be equal to the remaining number of years before 2020,

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[100] 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)

[101] 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.

i.e. for installations in 2012 the measure life should be 8 years, for installations in 2013 the measure life should be 7 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 CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Baseline		Efficient
	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$1.40[102]	$3.20[103]
Component Life[104] (years) Residential interior, in-unit Multi Family or unknown	0.91[105]	0.91[106]	7.3[107]
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[108]:

Residential interior, in-unit Multi Family or unknown

	NPV of baseline Replacement Costs
CFL wattage	2014
21W+	$5.96
16-20W	$5.96

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

[103] Ibid.

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

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

[106] 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.

[107] 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=cfls.pr_crit_cfls)

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

15W and less	$5.96

Multi Family Common Areas

	NPV of baseline Replacement Costs
CFL wattage	2014
21W+	$30.54
16-20W	$30.54
15W and less	$30.54

Hardwired CFL Fixtures (Exterior)*

Unique Measure Code(s): RS_LT_RTR_CFLFEX_0414 and RS_LT_INS_CFLFEX_0414
Effective Date: June 2014
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.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

Version 4 of this TRM introduces a new methodology for calculating the delta watts in this lighting measure; lumen equivalence. This requires the user to determine the bulb type, wattage and lumen rating of the efficient bulb and find a baseline bulb with equivalent lumens. Since this methodology requires a change to the information required to be collected for these measures and a potentially burden on utilities, the existing and new methodologies are both provided below. A single methodology should be used for all measures in a particular utility or program to prevent the potential implication of claiming whichever methodology provides higher savings.

Delta Watts Multiplier Method:

ΔkWh = #lamps * ((CFLwatts * DeltaMultiplier) /1000) * ISR * HOURS

Where:

CFLwatts = *CFL Lamp Watts (if known).*

DeltaMultiplier = *Multiplier to calculate delta watts. Depends upon bulb wattage and year of replacement*[109]*:*

CFL Wattage	Delta Watts Multiplier
	2014 and Beyond
15 or less	1.83
16-20	1.79
21W+	1.84

If Compact Fluorescent Watts is unknown use 58.5[110] *from 2013 onwards as the delta watts (i.e. for (CFLwatts * DeltaMultiplier)).*

See below for remaining variables

Lumen Equivalence Method:

ΔkWh = #lamps * ((WattsBase - WattsEE) /1000) * ISR * HOURS * $\text{WHFe}_{\text{Cool}}$ * $\text{WHFe}_{\text{Heat}}$

Where:

WattsBase = Based on lumens of CFL bulb[111]:

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[109] Average wattage of compact fluorescent from RLW study was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009. Post EISA multipliers are calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014); see MidAtlantic CFL Adjustments.xls.

[110] Calculated by multiplying 94.7 by the average adjustment 2014 percentage adjustment from table below. This adjustment should be made in 2013 since this is the midpoint of the 3 EISA adjustment years.

[111] Base wattage is based upon the post first phase of EISA wattage.

Minimum Lumens	Maximum Lumens	$\text{Watts}_{\text{Base}}$
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	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* [112]

HOURS = *Average hours of use per year*
= *1643 (4.5 hrs per day)*[113]

Illustrative example – do not use as default assumption
Delta Watts Multiplier method:

$$\Delta kWh = ((94.7) / 1000) * 0.87 * 1643$$

$$= 135 \text{ kWh}$$

Lumen Equivalence Method:
A 2 x 23W, 1600 lumen fixture is purchased and installed in an unknown location:

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

$$= 138 \text{ kWh}$$

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[112] 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).

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

Summer Coincident Peak kW Savings Algorithm

Delta Watts Multiplier Method:

ΔkW = (#lamps * (CFLwatts * DeltaMultiplier) /1000)) * ISR * CF

Lumen Equivalence Method:

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

Where:

CF = Summer Peak Coincidence Factor for measure
= 0.018 [114]

Illustrative example – do not use as default assumption
Delta Watts Multiplier Method:

ΔkW = (94.7 / 1000) * 0.87 * 0.018

= 0.0015 kW

Lumen Equivalence Method:
A 2 x 23W, 1600 lumen lamp fixture is purchased and installed in an unknown location:

ΔkW = (2* (72-23) / 1000) * 0.87 * 0.018

= 0.0015 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[115].

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

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

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[116] 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 CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Baseline		Efficient
	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$1.40[117]	$3.20[118]
Component Life (years) (based on lamp life / assumed annual run hours)	0.6[119]	0.6[120]	4.9[121]

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

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[116] 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.

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

[118] Ibid.

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

[120] 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.

[121] Assumes rated life of 8000 hours.

CFL wattage	NPV of baseline Replacement Costs[122] 2014
21W+	$7.42
16-20W	$7.42
15W and less	$7.42

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[122] 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_0414
Effective Date: June 2014
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[123]. 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

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

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

Where:

WattsBase = Connected load of baseline lamp

= Actual if retrofit, if LED lumens is known – find the equivalent baseline wattage from the table below[124]*, if unknown assume 65W* [125]

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

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

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

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
	500	649-1179[126]	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[127]	30

WattsEE = *Connected load of efficient lamp*
= *Actual. If unknown assume12W* [128]
ISR = *In Service Rate or percentage of units rebated that get installed.*
= *1.0*[129]
HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	3.0	1,100[130]
Multi Family Common Areas	16.3	5,950[131]
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[132]

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

[127] As above.

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

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

[130] Based on Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Lighting Program." April 4, 2014, page 56.

[131] 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.

[132] 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),

Building without cooling or exterior	1.0
Unknown	1.09[133]

$WHFe_{Heat}$ = *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[134]

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

= *47%*[135] *for interior or unknown location*

= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*

= *actual. If not available use*[136]*:*

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006	7.7	2.26
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.67[137]

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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).

[133] 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).

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

[135] 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.

[136] 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.

%ElecHeat = *Percentage of home with electric heat*

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[138]

Illustrative example – do not use as default assumption

Residential interior and in-unit Multi Family

$$\Delta kWh = ((65 - 12) / 1{,}000) * 1.0 * 1100 * (0.894 + (1.09 - 1))$$

$$= 57.4 \text{ kWh}$$

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*[139]
Building without cooling or exterior	1.0
Unknown	*1.18*[140]

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[137] 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.

[138] Based on KEMA baseline study for Maryland.

[139] 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).

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

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Coincidence Factor CF
Residential interior and in-unit Multi Family	0.09[141]
Multi Family Common Areas	0.43[142]
Exterior	0.018[143]
Unknown	0.09

Illustrative example – do not use as default assumption

ΔkW = ((65 – 12) / 1,000) * 1.0 * 1.18 * 0.09

= 0.0056 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):

$\Delta MMBtuPenalty$[144] = - ((((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.003412) / ηHeat) * %FossilHeat

Where:

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[145] *for interior or unknown location*
= *0% for exterior or unheated location*

0.003412 =*Converts kWh to MMBtu*

ηHeat = *Efficiency of heating system*
=*72%*[146]

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

[142] 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’.

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

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

[145] 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.

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

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[147]

Illustrative example – do not use as default assumption

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

ΔMMBtuPenalty = - (((65 – 12)/1000) * 1.0 * 1100 * 0.47 * 0.003412/0.75) * 1.0

= - 0.12 MMBtu

If home heating fuel is unknown:

ΔMMBtuPenalty = - (((65 - 12)/1000) * 1.0 * 1100 * 0.47 * 0.003412/0.72) * 0.625

= - 0.081 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 $61[148].

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[146] 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).

[147] Based on KEMA baseline study for Maryland.

[148] Based on VEIC product review, April 2011. Baseline bulbs available in $3-$5 range, and SSL bulbs available in $50-$80 range. Incremental cost of $61 therefore assumed ($4 for the baseline bulb and $65 for the SSL). Note, this product is likely to fall rapidly in cost, so this should be reviewed frequently. Product review, November 2012 and March 2014 suggests incremental cost estimate is still appropriate and wide range of costs available.

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[149].

Operation and Maintenance Impacts

The levelized baseline replacement cost over the lifetime of the SSL is calculated (see MidAtlantic CFL Adjustments_032014.xls). The key assumptions used in this calculation are documented below:

	BR-type Incandescent
Replacement Cost	$4.00
Component Life[150] (years) Residential interior and in-unit Multi Family or unknown.	1.7[151]
Multi Family Common Areas	0.34[152]

The calculated net present value of the baseline replacement costs is $27.80 for Residential interior and in-unit Multi Family and $151.72 for Multi Family common areas.

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[149] 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

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

[151] Assumes rated life of BR incandescent bulb of 2000 hours, based on product review. Lamp life is therefore 2000/1100 = 1.8 years.

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

ENERGY STAR Integrated Screw Based SSL (LED) Lamp*

Unique Measure Code: RS_LT_TOS_SSLDWN_0414
Effective Date: June 2014
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 August 2010) in place of an incandescent lamp. This measure is broken down in to Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16). Further, the Omnidirectional are broken down in to <10W and >=10W and Directional Lamps in to <15W and >=15W categories to best reflect the delta wattage in each range. The ENERGY STAR specification can be viewed here: http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf?e1ab-be93

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

Definition of Baseline Condition

The baseline wattage is assumed to be an incandescent bulb installed in a screw-base socket.

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

Version 4 of this TRM introduces a new methodology for calculating the delta watts in this lighting measure; lumen equivalence. This requires the user to determine the bulb type, wattage and lumen rating of the efficient bulb and find a baseline bulb with equivalent lumens. Since this methodology requires a change to the information required to be collected for these measures and a potentially burden on utilities, the existing and new methodologies are both provided below. A single methodology should be used for all measures in a particular utility or program to prevent the potential implication of claiming whichever methodology provides higher savings.

Delta Watts Multiplier Method:

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

Where:

LEDwatts = *LED Lamp Watts (if known). If unknown assume 14.5W (replacing 60W incandescent)* [153]

DeltaMultiplier = *Multiplier to calculate delta watts. Depends upon bulb type, wattage and year of replacement*[154]

Omnidirectional Lamps

			Pre-EISA Incandescent Baseline	Post 2012-2014 EISA Incandescent Baseline			Post 2020 EISA CFL baseline	
Nominal wattage of lamp to be replaced (watts)	Minimum initial light output of LED lamp (lumens)	LED Wattage[155] (<10W - 50 lm/W, >=10W - 55 lm/W)	Delta Watts Multiplier	Baseline wattage	Year of change	Delta Watts Multiplier	Baseline wattage (45 lm/W)	Delta Watts Multiplier
25	200	4.0	5.3	25	n/a	5.3	25	5.3
35	325	6.5	4.4	35	n/a	4.4	35	4.4
40	450	9.0	3.4	29	2014	2.2	10.0	0.1
60	800	14.5	3.1	43	2014	2.0	17.8	0.2
75	1,100	20.0	2.8	53	2013	1.7	24.4	0.2
100	1,600	29.1	2.4	72	2012	1.5	35.6	0.2
125	2,000	36.4	2.4	125	n/a	2.4	125	2.4
150	2,600	47.3	2.2	150	n/a	2.2	150	2.2

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

[154] Based on ENERGY STAR specification standards. See 'ESTAR Integrated Screw SSL Lamp.xls' for details.

[155] Wattage is calculated using the details of the ENERGY STAR specification linked in the measure description. For LED <10W the minimum luminous efficacy is 50 lumens per watt, for >=10W it is 55 lumens per watt.

Decorative Lamps

Nominal wattage of lamp to be replaced (watts)	Minimum initial light output of LED lamp (lumens)	LED Wattage (40 lm/W)	Delta Watts Multiplier
10	70	1.8	4.7
15	90	2.3	5.7
25	150	3.8	5.7
40	300	7.5	4.3
60	500	12.5	3.8

Directional Lamps

Nominal wattage of lamp to be replaced (watts)	Minimum initial light output of LED lamp (lumens)	LED Wattage (<=20/8" diameter - 40 lm/W, >20/8" diameter - 45 lm/W)	Delta Watts Multiplier
25	250	6.3	3.0
35	350	8.8	3.0
40	400	10.0	3.0
60	600	15.0	3.0
75	750	16.7	3.5
100	1000	22.2	3.5
125	1250	27.8	3.5
150	1500	33.3	3.5

See below for remaining variables

Lumen Equivalence Method:

ΔkWh = ((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*[156]*;*
If unknown assume 14.5W[157]

Bulb Type	Lower Lumen Range	Upper Lumen Range	WattsBase
Standard Spirals	250	309	25
	310	749	29
	750	1049	43
	1050	1489	53
	1490	2600	72
	2601	2999	150
	3000	5279	200
	5280	6209	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

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

[157] 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
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
	1730	2189	100
	2190	2899	120
	2900	3850	150
***ER30, BR30, BR40, or ER40**	400	449	40
	450	499	45
	500	649-1179[158]	50
***BR30, BR40, or ER40**	650	1419	65
***R20**	400	449	40
	450	719	45
***All reflector lamps**	200	299	20

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[158] 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
below lumen ranges specified above	300	399-639[159]	30

ISR = *In Service Rate or percentage of units rebated that get installed.*
= *0.95*[160]

HOURS = *Average hours of use per year*

Installation Location	Daily Hours	Annual Hours
Residential interior and in-unit Multi Family	3.0	1,100[161]
Multi Family Common Areas	16.3	5,950[162]
Exterior	4.5	1,643[163]
Unknown	3.0	1,100[164]

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

	$WHFe_{Cool}$
Building with cooling	1.12[165]

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[159] As above.

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

[161] Based on Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Lighting Program.” April 4, 2014, page 56.

[162] 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.

[163] 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

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

[165] 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).

Building without cooling or exterior	1.0
Unknown	1.09[166]

$WHFe_{Heat}$ = *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[167]

HF = *Heating Factor or percentage of light savings that must be heated*
= *47%*[168] *for interior or unknown location*
= *0% for exterior or unheated location*

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[169]*:*

System Type	Age of Equipment	HSPF Estimate	ηHeat (COP Estimate)
Heat Pump	Before 2006	6.8	2.00
	After 2006	7.7	2.26
Resistance	N/A	N/A	1.00
Unknown	N/A	N/A	1.67[170]

%ElecHeat = *Percentage of home with electric heat*

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[166] 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).

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

[168] 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.

[169] 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.

[170] 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.

Heating fuel	%ElecHeat
Electric	100%
Fossil Fuel	0%
Unknown	37.5%[171]

Illustrative example – do not use as default assumption

Delta Watts Multiplier Method:
A 15W omnidirectional LED lamp is installed in a residential interior location in 2014.

$$\Delta kWh = ((15 * 2.0)/ 1{,}000) * 0.95 * 1100 * (0.894 + (1.09 – 1))$$

$$= 30.8\ kWh$$

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

$$\Delta kWh = ((50 - 10)/ 1{,}000) * 0.95 * 1100 * (0.894 + (1.09 – 1))$$

$$= 41.1\ kWh$$

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[172]:

Minimum initial light output of LED lamp (lumens)	Mid life Adjustment in 2020
200	100%
325	100%

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[171] Based on KEMA baseline study for Maryland.
[172] See 'ESTAR Integrated Screw SSL Lamp_032014.xls' for details.

450	5%
800	11%
1,100	13%
1,600	15%
2,000	100%
2,600	100%

Summer Coincident Peak kW Savings Algorithm

Delta Watts Multiplier Method:

$$\Delta kW = ((LEDwatts * DeltaMultiplier) / 1000) * ISR * WHFd * CF$$

Lumen Equivalence Method:

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

Where:

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

	WHFd
Building with cooling	*1.24*[173]
Building without cooling or exterior	1.0
Unknown	*1.18*[174]

CF = *Summer Peak Coincidence Factor for measure*

Installation Location	Coincidence Factor CF
Residential interior and in-unit Multi Family	0.09[175]
Multi Family Common Areas	0.43[176]

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[173] 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).

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

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

Exterior	0.018[177]
Unknown	0.09

Illustrative example – do not use as default assumption

Delta Watts Multiplier Method:
A 15W omnidirectional LED lamp is installed in a residential interior location in 2014:

$$\Delta kW = ((15 * 2.0)/ 1{,}000) * 0.95 * 1.18 * 0.11$$

$$= 0.0037 \text{ kW}$$

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

$$\Delta kW = ((50 – 10)/ 1{,}000) * 0.95 * 1.18 * 0.11$$

$$= 0.0049 \text{ kW}$$

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 Watts Multiplier Method:

ΔMMBtuPenalty[178] = - ((((LEDwatts * DeltaMultiplier) / 1000) * ISR * Hours * HF * 0.003412) / ηHeat) * %FossilHeat

Lumen Equivalence Method:

ΔMMBtuPenalty = - ((((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.003412) / ηHeat) * %FossilHeat

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[176] 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'.

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

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

Where:

HF = Heating Factor or percentage of light savings that must be heated
= 47%[179] *for interior or unknown location*
= 0% for exterior or unheated location
0.003412 =Converts kWh to MMBtu
ηHeat = Efficiency of heating system
=72%[180]
%FossilHeat = Percentage of home with non-electric heat

Heating fuel	%FossilHeat
Electric	0%
Fossil Fuel	100%
Unknown	62.5%[181]

Illustrative example – do not use as default assumption

Delta Watts Multiplier Method:
A 15W omnidirectional LED lamp is installed in in 2014 in a home with unknown heating fuel:

ΔMMBtuPenalty = - ((15 * 2.0)/ 1,000) * 0.95 * 1100 * 0.47 * 0.003412/0.72) * 0.625

= - 0.044 MMBtu

Lumen Equivalence Method:
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.

ΔMMBtuPenalty = - ((50 - 10)/ 1,000) * 0.95 * 1100 * 0.47 * 0.003412/0.72) * 0.625

---

[179] 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.

[180] 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).

[181] Based on KEMA baseline study for Maryland.

= - 0.058 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 :

		Lamp Costs				Incremental Cost		
		Efficient	Baseline					
	LED Wattage	LED	Incandescent	EISA 2012-2014 Compliant	EISA 2020 Compliant	Incandescent	EISA 2012-2014 Compliant	EISA 2020 Compliant
Omni-directional	<10W	$28.29	n/a	$1.23	$2.86	n/a	$27.06	$25.43
	>=10W	$34.42	n/a	$1.41	$3.19	n/a	$33.01	$31.23
Decorative	All	$23.64	$3.40	n/a	n/a	$20.24	n/a	n/a
Directional	<15W	1$48.10	$6.16	n/a	n/a	$41.94	n/a	n/a
	>=15W	$57.94	$6.47	n/a	n/a	$51.47	n/a	n/a

Measure Life

The measure life is assumed to be:

	Rated Life[183]	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	14	2.5	9.1
Directional	25,000	20	4.2	15.2

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[182] All costs based on "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28, 2014. See "Itron Lighting Incremental Cost.xlsx".

[183] 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.

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[184]		
		Residential interior, in-unit Multi Family and unknown	Multi Family Common Areas	Exterior
Decorative	$3.40	0.91	0.2	0.6
Directional <15W	$6.16	0.91	0.2	0.6
Directional >=15W	$6.47	0.91	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.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)[185]

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

NPV of baseline

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

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

			Replacement Costs
	Location	LED Wattage	2014
Omnidirectional	Residential interior, in-unit Multi Family and unknown	<10W	$9.02
		>=10W	$10.25
	Multi Family Common Areas	<10W	$25.86
		>=10W	$29.65
	Exterior	<10W	$12.22
		>=10W	$13.92

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):[186]

Product Category	Volume (cubic feet)	Assumptions up to September 2014		Assumptions after September 2014	
		Federal Baseline Maximum Energy Usage in kWh/year[187]	ENERGY STAR Maximum Energy Usage in kWh/year[188]	Federal Baseline Maximum Energy Usage in kWh/year[189]	ENERGY STAR Maximum Energy Usage in kWh/year[190]
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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[186] http://www.energystar.gov/ia/products/appliances/refrig/NAECA_calculation.xls?c827-f746

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

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

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

[190] 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:

ΔkWh =(7.55 * (12 * 1.73) + 258.3) – (6.795 * (12 * 1.73) + 232.47)

= 359.5 – 323.6

= 41.5 kWh

If volume is unknown, use the following default values:

Product Category	Volume Used[191]	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%

---

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

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%

If configuration is unknown assume 58.8 kWh[192] for installations before September 1, 2014 and 41.2kWh 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 [193]
LSAF = Load Shape Adjustment Factor
= 1.15 [194]

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

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[192] 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.

[193] 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.

[194] 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).

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

$$= 0.0067 \text{ kW}$$

If volume is unknown, use the following default values:

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[195].

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[195] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products

Measure Life

The measure life is assumed to be 12 years[196].

Operation and Maintenance Impacts

n/a

Initiative. "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009.

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

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[197]	ENERGY STAR Maximum Energy Usage in kWh/year[198]	Federal Baseline Maximum Energy Usage in kWh/year[199]	ENERGY STAR Maximum Energy Usage in kWh/year[200]
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

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

5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service	4.60*AV+459	3.68*AV+367.2	8.85AV + 317.0	7.97 * AV + 285.3
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:

ΔkWh =((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[201]:

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

---

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

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
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[202] 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.

Summer Coincident Peak kW Savings Algorithm

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

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[202] 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.

Where:

TAF = Temperature Adjustment Factor
= 1.23 [203]

LSAF = Load Shape Adjustment Factor
= 1.15 [204]

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

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[203] 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.

[204] 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).

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 through-the-door ice service	0.019	0.023	0.008	0.023
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[205] and $140 for a CEE Tier 2 unit.[206]

Measure Life

The measure life is assumed to be 12 Years.[207]

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

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

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

Operation and Maintenance Impacts

n/a

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[208])

$$\Delta kWh = kWhEXIST - kWhEE$$

Remaining measure life (next 8 years)

$$\Delta kWh = kWhBASE - kWhEE$$

---

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

Where:

kWhEXIST = *Annual energy consumption of existing unit*
= *1146* [209]

kWhBASE = *Annual energy consumption of new baseline unit*
= *572.3 for units prior to September 2014*
= *511.7 for units after September 2014*[210]

kWhEE = *Annual energy consumption of ENERGY STAR unit*
= *457.8 for units prior to September 2014*
= *462.6 for units after September 2014*[211]

Or = *Annual energy consumption of CEE Tier 2 unit*
= *429.2 for units prior to September 2014*
= *383.8 for units after September 2014*[212]

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[213]
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

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

[210] 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.

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

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

[213] 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.

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

Where:

TAF = Temperature Adjustment Factor
= 1.23 [214]

LSAF = Load Shape Adjustment Factor
= 1.15 [215]

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.[216]

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[214] 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.

[215] 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).

[216] 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

Measure Life

The measure life is assumed to be 12 Years. [217]

Operation and Maintenance Impacts

n/a

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of Amended Energy Conservation Standards for Residential Refrigerator-Freezers". http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrigerator_report_1.pdf

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

Refrigerator and Freezer Early Retirement*

Unique Measure Code(s): RS_RF_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[218] 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[219].

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[220]:

Independent Variable Description	Estimate Coefficient
Intercept	0.582
Age (years)	0.027

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[218] 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.

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

[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 32.

Pre-1990 (=1 if manufactured pre-1990)	1.055
Size (cubic feet)	0.067
Dummy: Single Door (=1 if single door)	-1.977
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

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

Where:

HDD = *Heating Degree Days*
= *dependent on location. Use actual for location or defaults below*[221]

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*[222]

Location	*Cooling Degree*	*CDD / 365.25*

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[221] 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.

[222] Ibid.

	Days (65˚F set point)	
Wilmington, DE	*1,162*	*3.2*
Baltimore, MD	*1,266*	*3.5*
Washington, DC	*1,431*	*3.9*

Part Use Factor = *To account for those units that are not running throughout the entire year as reported by the customer. Default of 0.89*[223]

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

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

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

$$= 761 \text{ kWh}$$

Freezers:

Energy savings for freezers are based upon a linear regression model using the following coefficients[224]:

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

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

[224] 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.

Interaction: Located in Unconditioned Space x HDD/365.25	0.070
Interaction: Located in Unconditioned Space x CDD/365.25	-0.031

$$\Delta kWh = [-0.892 + (Age * 0.038) + (Pre\text{-}1990 * 0.695) + (Size * 0.129) + (Chest\ Freezer * 0.35) + (HDDs/365.25 * Unconditioned * 0.070) + (CDDs/365.25 * Unconditioned * -0.031)] * 365.25 * Part\ Use\ Factor$$

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:

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

$$= 639\ kWh$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor
= 1.23 [225]

LSAF = Load Shape Adjustment Factor
= 1.066 [226]

---

[225] 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.

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

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

Refrigerator:

ΔkW = 761/8760 * 1.23 * 1.066

= 0.114 kW

Freezer:

ΔkW = 639/8760 * 1.23 * 1.066

= 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.[227]

Operation and Maintenance Impacts

n/a

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

Heating Ventilation and Air Conditioning (HVAC) End Use

Central Furnace Efficient Fan Motor

Unique Measure Code(s): RS_HV_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 [228]

Cooling Season kWh Savings from efficient fan motor = 178kWh [229]

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[228] 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).

[229] 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

Summary Coincident Peak kW Savings Algorithm

$\Delta kW = 0$ [230]

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.[231]

Measure Life

The measure life is assumed to be 18 years.[231]

Operation and Maintenance Impacts

n/a

95kWh. An estimate for Mid-Atlantic is provided by multiplying by the ratio of full load cooling hours in Baltimore compared to Southern Wisconsin (1050/487). Full load hour estimates from: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls.

[230] 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.

[231] 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[232] presented above.

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[232] 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.

Definition of Efficient Condition

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 [233]
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 [234]
EERbase *= Efficiency of baseline unit in Btus per Watt-hour*
= Actual (see table above)
If average deemed value required use 10.9 [235]
EERee *= Efficiency of ENERGY STAR unit in Btus per Watt-hour*
= Actual
If average deemed value required use 11.3 [236] *for an ENERGY STAR unit or 11.8 for CEE Tier 2* [237]

Using deemed values above:

$\Delta kWH_{ENERGY\ STAR}$

---

[233] 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.

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

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

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

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

= (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

Summer Coincident Peak kW Savings Algorithm

ΔkW = 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 [238]

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[239]

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

---

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

[239] 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).

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 $40 for an ENERGY STAR unit and $80 for a CEE TIER 2 unit.[240]

Measure Life

The measure life is assumed to be 12 years.[241]

Operation and Maintenance Impacts

n/a

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

[241] 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_0414, RS_HV_RTR_CENA/C_0414
Effective Date: June 2014
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.

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[242]:

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* [243]
Baltimore, MD	*542* [244]
Washington, DC	*681*

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

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

---

[242] 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).

[243] 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)

[244] 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.

= 13[245]

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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[245] Minimum Federal Standard.

[246] 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 [247]
EERexist = EER Efficiency of existing unit
= Actual EER of unit should be used, if EER is unknown, use 9.2[248]
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 [249]
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 [250]

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

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

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

---

[247] 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).

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

[249] 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.

[250] 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.

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

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:[251]

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

---

[251] 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.

SEER 20	$642
SEER 21	$734

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)[252]:

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[253]. This cost should be discounted to present value using the utilities discount rate.

Measure Life

The measure life is assumed to be 18 years.[254]

Remaining life of existing equipment is assumed to be 6 years[255].

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[252] 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).

[253] Ibid.

[254] 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

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

Operation and Maintenance Impacts

n/a

Duct Sealing

Unique Measure Code: RS_HV_RTR_DCTSLG_0711
Effective Date: June 2014
End Date: TBD

Measure Description

This measure is the sealing of ducts using mastic sealant or metal tape.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first method requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p44 of the Energy Conservatory Blower Door Manual; http://www.energyconservatory.com/download/bdmanual.pdf

2. **Evaluation of Distribution Efficiency** – this methodology requires the 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

This is a retrofit measure.

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

Cooling savings from reduction in Air Conditioning Load:

Methodology 1: Modified Blower Door Subtraction

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

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

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 $CFM25_{DL}$[256] and factor in Supply and Return Loss Factors

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

Where:

SLF = Supply Loss Factor
*= % leaks sealed located in Supply ducts * 1* [257]
Default = 0.5[258]

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

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

RLF = *Return Loss Factor*
= *% leaks sealed located in Return ducts * 0.5*[259]
Default = 0.25[260]

c. Calculate Energy Savings:

$\Delta kWh_{cooling}$ = ((ΔCFM25$_{DL}$)/ (Capacity * 400)) * FLHcool * BtuH) / 1000 / ηCool

Where:

ΔCFM25$_{DL}$ = *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* [261]
Baltimore, MD	*542* [262]
Washington, DC	*681*

BtuH = *Size of equipment in Btuh (note 1 ton = 12,000Btuh)*
= *Actual*
ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available use*[263]*:*

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

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

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

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

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

[263] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

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:

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

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

Duct Leakage reduction at CFM25:

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

Energy Savings:

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

---

system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

= 170 kWh

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

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

Where:

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

Capacity = Capacity of Air Cooling system (tons)

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

FLHheat = Full Load Heating Hours

= Dependent on location as below:

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

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

= Actual

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use[266]*:*

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*

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[264] Full Load Heating Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (1195 from the research referenced below) by the ratio of full load hours in Wilmington, DE (2346) or Washington, DC (2061) to Baltimore MD (2172) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

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

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

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:

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

= 362 kWh

Methodology 2: Evaluation of Distribution Efficiency

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

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

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

Where:

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

Location	*FLHcool*
Wilmington, DE	*524* [267]
Baltimore, MD	*542* [268]
Washington, DC	*681*

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual
ηCool = Efficiency in SEER of Air Conditioning equipment
= actual. If not available use[269]*:*

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[267] 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)

[268] 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.

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

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:

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

$$= 191 \text{ kWh}$$

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

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

Where:

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

Location	FLHheat
Wilmington, DE	*935*[270]
Baltimore, MD	*866*[271]
Washington, DC	*822*

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

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[269] 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.

[270] 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)

[271] 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.

= Actual

ηHeat = *Efficiency in COP of Heating equipment*

= *actual. If not available use*[272]*:*

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*

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:

ΔkWh = ((((0.90 – 0.80)/0.90) * 866 * 36,000) / 1,000,000 / 2.5) * 293.1

= 406 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* [273]

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* [274]

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[272] 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.

[273] 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.

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

Methodology 1: Modified Blower Door Subtraction

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

Where:

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

BtuH = *Capacity of Heating System (Btuh)*

= *Actual*

0.0126 = *Conversion of Capacity to CFM (0.0126CFM / Btuh)*[275]

FLHheat = *Full Load Heating Hours*

= *620*[276]

ηHeat = *Efficiency of Heating equipment*

= *Actual*[277]*. If not available use 84%*[278].

Illustrative example – do not use as default assumption

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

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[274] 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.

[275] 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.

[276] 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.

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

[278] 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%.

Energy Savings:

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

= 7.3 MMBtu

Methodology 2: Evaluation of Distribution Efficiency

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

Where:

DE_{after} = *Distribution Efficiency after duct sealing*
DE_{before} = *Distribution Efficiency before duct sealing*
FLHheat = *Full Load Heating Hours*
= *620*[279]
BtuH = *Capacity of Heating System*
= *Actual*
ηHeat = *Efficiency of Heating equipment*
= *Actual*[280]*. If not available use 84%*[281].

Illustrative example – do not use as default assumption

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

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

Energy Savings:

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

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

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

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

= 8.6 MMBtu

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.

Measure Life

The measure life is assumed to be 20 years[282].

Operation and Maintenance Impacts

n/a

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

Air Source Heat Pump*

Unique Measure Code: RS_HV_TOS_ASHP_0414, RS_HV_RTR_ASHP_0414,
Effective Date: June 2014
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[283]
Federal Standard	7.7	13	11
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.

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 as defined above for the remainder of the measure life.

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

Definition of Efficient Condition

The efficient condition is an Air Source Heat Pump split system that meets the ENERGY STAR standards defined above.

Annual Energy Savings Algorithm

Time of Sale:

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

Early replacement[284]:

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

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

ΔkWH for remaining measure life (next 12 years):

$$= (FLHcool * BtuH_{Cool} * (1/SEERbase - 1/SEERee))/1{,}000 + (FLHheat * BtuH_{Heat} * (1/HSPFbase - 1/HSPFee))/1{,}000$$

Where:

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	FLHcool
Wilmington, DE	*719* [285]
Baltimore, MD	*744* [286]
Washington, DC	*935*

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[284] 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).

[285] 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)

[286] 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.

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

SEERbase = *Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump*
= 13[287]

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*[288]
Air Source Heat Pump or Central AC	*10.0*
No central cooling[289]	*Make '1/SEERexist' = 0*

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

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

Location	**FLHheat**
Wilmington, DE	*935*[290]
Baltimore, MD	*866*[291]
Washington, DC	*822*

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[287] Minimum Federal Standard

[288] 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.

[289] 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.

[290] 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)

[291] 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.

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

HSPFbase = *Heating Seasonal Performance Factor of baseline Air Source Heat Pump*
= *7.7* [292]

HSPFexist = *Heating System Performance Factor*[293] *of existing heating system (kBtu/kWh)*

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

Existing Heating System	*HSPF_exist*
Air Source Heat Pump	*5.96* [294]
Electric Resistance	*3.41*[295]

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

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:

$$\Delta kWH = (744 * 36{,}000 * (1/13 - 1/14.5))/1{,}000 + (866 * 36{,}000 * (1/7.7 – 1/8.4))/1{,}000$$

$$= 550 \text{ kWh}$$

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:

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[292] Minimum Federal Standard

[293] 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.

[294] 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.

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

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 7 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

Summer Coincident Peak kW Savings Algorithm

Time of Sale:

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

Early replacement:

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

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

ΔkW for remaining measure life (next 12 years):

$= BtuH_{Cool} * (1/EERbase - 1/EERee)/1000 * CF$

Where:

EERbase = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*
= *11.2* [296]

EERexist = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

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

$EER = (-0.02 * SEER^2) + (1.12 * SEER)$ [297]

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[296] 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).

If SEER rating unavailable use:

Existing Cooling System	EERexist[298]
Air Source Heat Pump or Central AC	9.2
No central cooling[299]	Make ‘1/EERexist’ = 0

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

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [300]

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* [301]

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:

$$\Delta kW_{SSP} = 36{,}000 * (1/11.2 - 1/12))/1{,}000 * 0.69$$

$$= 0.15\ kW$$

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):

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

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

[299] 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.

[300] 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.

[301] 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_{SSP} = 36,000 * (1/9.2 - 1/12))/1,000 * 0.69

= 0.63 kW

ΔkW for remaining measure life (next 12 years):

ΔkW_{SSP} = 36,000 * (1/11 - 1/12))/1,000 * 0.69

= 0.15 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[302]. Note these incremental costs are per ton of capacity, so for example a 3 ton, 15 SEER unit would have an incremental cost of $822.

Efficiency (SEER)	Incremental Cost per Ton of Capacity
14	$208
15	$378
16	$548
17	$737
18	$918

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)[303]:

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[302] 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.

[303] 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.

Efficiency (SEER)	Full Retrofit Cost (including labor) per Ton of Capacity ($/ton)
14	$2,355
15	$2,544
16	$3,120
17	$3,309
18	$3,614

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $2,166 per ton of capacity[304]. This cost should be discounted to present value using the utilities discount rate.

Measure Life

The measure life is assumed to be 18 years[305].

Operation and Maintenance Impacts

n/a

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[304] Ibid.

[305] 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_0414, RS_HV_RTR_ASHP_0414
Effective Date: June 2014
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
2014	13	10	7.7
2015	14	8.5	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:

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[306] *for Central AC or 8.5 for Room AC*[307]*. If no cooling exists but the customer is looking for a cooling solution, assume 13.0. 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).*

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[306] 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.

[307] 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.

Time of Sale / New Construction = 13.0[308]

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

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

= Actual[309]

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[310] *for resistance heat,* 5.96[311] for ASHP.

Time of Sale / New Construction = 7.7 [312]

HSPFee = Heating Seasonal Performance Factor of ENERGY STAR ductless heat pump[313]
= Actual

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

= Actual[314]

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[308] Minimum Federal Standard

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

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

[311] 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.

[312] Minimum Federal Standard

[313] 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.

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
= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 78%[315]*.*

3.412 = Converts heat pump HSPF in to COP

See example calculations at end of characterization.

Summer Coincident Peak kW Savings Algorithm

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

Where:

$BtuH_{Cool}$ = Cooling capacity of ductless heat pump (1 ton = 12,000Btuh)
= 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[316] *for Central AC or 7.7 for Room AC*[317]*.*

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

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

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

[317] 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.”

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 = 11.2[318]

EERee = Energy Efficiency Ratio (EER) of Efficient ductless heat pump
= 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 [319]

$CF_{PJM\ Room\ AC}$ *= 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[320]

$CF_{SSP\ Central\ AC}$ *= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= 0.69 [321]

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[318] 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).

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

[320] 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).

[321] 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.

$CF_{PJM\ Central\ AC}$ = 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 [322]

See example calculations at end of characterization.

Annual Fossil Fuel Savings Algorithm

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

$$\Delta MMBtu = HeatLoadGasReplaced / AFUEexist$$

Where:

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

= Actual[323]

AFUEexist = Efficiency of existing heating system
= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 78%[324].

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

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[322] 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.

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

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

if available, if not defaults are provided in the table below:

Unit Size	Early Replacement: Full Install Cost[325]
1-Ton	$3,000
1.5-Ton	$3750
2-Ton	$4,500
2.5-Ton	$5,250
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[326].

Central Ducted Air Source Heat Pump - $2,166 per ton[327]

Furnace - $2,311 [328]

Boiler - $3,834 [329]

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.

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[325] 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.

[326] 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).

[327] Ibid.

[328] 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.

[329] Ibid. Labor estimated as $500.

Time of Sale / New construction: an estimated incremental cost from a SEER 13 baseline is provided below:

Unit Size	Time of Sale / New Construction: Incremental Cost[330]
1-Ton	$603
1.5-Ton	$624
2-Ton	$601
2.5-Ton	$600
3-Ton	$600

Measure Life

The measure life is assumed to be 18 years[331]. If an early replacement measure results in the removal of existing operating heating or cooling equipment, it is assumed that it would have needed replacing in 6 years.

Operation and Maintenance Impacts

n/a

Illustrative examples – do not use as default assumption

Early Replacement:

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

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[330] 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.

[331] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. https://neep.org/Assets/uploads/files/emv/emv-library/measure_life_GDS%5B1%5D.pdf

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} = $BtuH_{Cool}$ * (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} = $BtuH_{Cool}$ * (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 * (1/13 – 1/18)) + (12,000 * (3.412/7.7 – 3.412/11))

= 1,723 kWh

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

= (36,000 * (1/11.2 – 1/13.5)) / 1000) * 0.31

= 0.17 kW

HE Gas Boiler

Unique Measure Code: RS_HV_TOS_GASBLR_0113
Effective Date: June 2014
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.

Definition of Baseline Condition

The baseline condition is a boiler that meets the minimum Federal baseline AFUE for boilers. The Federal baseline for boilers manufactured before September 2012 was 80% AFUE. For boilers manufactured after September 2012, the Federal baseline is 82% AFUE.

Year	Baseline AFUE
2012	80%
2013 on	82%

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

ΔMMBtu = (FLHheat * (Btuh/AFUEbase - Btuh/AFUEee)) /1,000,000

Where:

FLHheat = Full Load Heating Hours
= 620[332]

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[332] Based on assumption from BG&E billing analysis of furnace program in the '90s, from conversation with Mary Straub; "Evaluation of the High efficiency heating and cooling program,

BtuH = *Capacity of Boiler*
= *Actual*

AFUEbase = *Efficiency in AFUE of baseline boiler*

Year	Baseline AFUE
2012	80%
2013 on	82%

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

Illustrative example – do not use as default assumption
The purchase and installation of a 100,000 Btuh, 90% AFUE boiler in 2013:

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

= 6.7 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

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

Efficiency of Boiler (AFUE)	Incremental Cost 2012	Incremental Cost 2013
85% - 90%	$934	$725
91% +	$1481	$1272

Measure Life

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

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

[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.

[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

Operation and Maintenance Impacts

n/a

Condensing Furnace (gas)

Unique Measure Code: RS_HV_TOS_GASFUR_0113
Effective Date: June 2014
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.

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

$$\Delta MMBtu = (FLHheat * (Btuh/AFUEbase - Btuh/AFUEee)) /1,000,000$$

Where:

FLHheat = Full Load Heating Hours

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[335] The Federal baseline for furnaces is actually 78%, although it becomes 80% in May 2013. Experience suggests a suitable market baseline is 80% AFUE.

= 620[336]

BtuH = Capacity of Furnace

= Actual

AFUEbase = Efficiency in AFUE of baseline Furnace

= 0.80

AFUEee = Efficiency in AFUE of efficient Furnace

= Actual

Illustrative example – do not use as default assumption
The purchase and installation of a 100,000 Btuh, 92% AFUE furnace:

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

= 10.1 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below[337]:

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

Measure Life

The measure life is assumed to be 18 years[338].

Operation and Maintenance Impacts

n/a

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[336] 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.

[337] 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

[338] 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

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

Where:

Savings % = *Estimated percent reduction in heating load due to programmable thermostat*
= *6.8%* [339]

Heat Consumption = *Annual Home Heating* Consumption *(MMBtu)*
= *50.1* [340]

$$\Delta\text{MMBtu} = 0.068 * 50.1$$

$$= 3.41 \text{ MMBtu}$$

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[341].

Measure Life

The measure life is assumed to be 10 years[342].

Operation and Maintenance Impacts

n/a

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[339] 2007, RLW Analytics, "Validating the Impact of Programmable Thermostats"

[340] 50.1 MMBtu heating consumption is estimated based on the MD Residential Baseline Database, subtracting Base load from Base + Heat.

[341] 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.

[342] 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[343]).

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 [344]).

Annual Energy Savings Algorithm

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

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

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

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

Savings for remaining measure life (next 9 years)

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

Where:

Hours = *Run hours of Window AC unit*
= *325* [345]

Btuh = *Capacity of replaced unit*
= *Actual or 8,500 if unknown* [346]

EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *7.7* [347]

EERbase = *Efficiency of baseline unit in Btus per Watt-hour*
= *10.9* [348]

EERee = *Efficiency of ENERGY STAR unit in Btus per Watt-hour*
= *Actual*

Illustrative example – do not use as default assumption
Replacing existing 8,500 Btuh 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

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[345] 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.

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

[347] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

[348] Minimum Federal Standard for capacity range.

Summer Coincident Peak kW Savings Algorithm

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

$\Delta kW = ((BtuH * (1/EERexist - 1/EERee))/1000) * CF$

Savings for remaining measure life (next 9 years)

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

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [349]

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*[350]

Illustrative example – do not use as default assumption
Replacing existing 8,500 Btuh 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)

$\Delta kW_{SSP} = ((8{,}500 * (1/7.7 – 1/11.3)) / 1{,}000) * 0.31$

$= 0.11$ kW

Savings for remaining measure life (next 9 years)

$\Delta kW_{SSP} = ((8{,}500 * (1/10.9 – 1/11.3)) / 1{,}000) * 0.31$

$= 0.0086$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

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

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

n/a

Incremental Cost

The incremental cost for this measure should be the actual cost of the replacement unit and any cost of installation labor.

Note, the deferred baseline replacement cost is presented under Operation and Maintenance Impacts.

Measure Life

The measure life is assumed to be 12 years[351]. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced[352].

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[353]) * 69%[354].

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

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[351] 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

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

[353] Incremental cost of ENERGY STAR unit over baseline unit; consistent with Time of Sale Room AC measure.

[354] 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

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

Where:

Hours = Run hours of Window AC unit
= 325 [355]

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[355] 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

Btu/hour = *Capacity of replaced unit*
= *Actual or 8,500 if unknown* [356]
EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *Actual or 7.7 if unknown* [357]
%replaced = Percentage of units dropped off that are replaced in the home
= 76% [358]
EERnewbase = *Efficiency of new baseline unit in Btus per Watt-hour*
= 10.9[359]

Illustrative example – do not use as default assumption
The turn in of an 8,500 Btuh, 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

$$\Delta kW = ((BtuH * (1/EERexist))/1{,}000) - (\%replaced * ((BtuH * (1/EERnewbase))/1{,}000) * CF$$

Where:

CF_{SSP} = *Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [360]

31%. Applying this to the FLH for Central Cooling provided for Baltimore (1050) we get 325 FLH for Room AC.

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

[357] Based on Nexus Market Research Inc, RLW Analytics, December 2005; "Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report."

[358] 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.

[359] 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.

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

CF_{PJM} = *PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= 0.3[361]

Illustrative example – do not use as default assumption
The turn in of an 8500 Btuh, 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[362].

Measure Life

The measure life is assumed to be 3 years[363].

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

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[361] 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).

[362] $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.

[363] 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

standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $89.36[364].

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[364] 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)

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[365] = ((((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

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

= 2.5 [366] *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.

 # people = Average number of people per household

= 2.56 [367]

gals/day = Average gallons per day used for showering

= 11.6 [368]

days/y = Days shower used per year

= 365

Showers/home = Average number of showers in the home

= 1.6 [369]

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 [370]

DHW Recovery Efficiency = Recovery efficiency of electric water heater

= 0.98 [371]

0.003412 = Constant to convert MMBtu to kWh

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

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

[368] 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)

[369] 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

[370] 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.

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

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

$$\Delta kWH = ((((2.5 – 2.0) / 2.5) *2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-60.9) / 1,000,000) / 0.98 / 0.003412$$

$$= 148 \text{ kWh}$$

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

Summer Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Average number of hours per year spent using shower head*
= *(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* [372]

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:

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[372] 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

ΔMMBtu = ((((GPMbase - GPMlow) / GPMbase) * # people * gals/day * days/year)) / SH/home * 8.3 * (TEMPsh - TEMPin) / 1,000,000) / Gas DHW Recovery Efficiency

Where:

Gas DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.75 [373]
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

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[373] Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

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

$$\Delta kWh_{water}{}^{374} = 2.07\ kWh * \Delta Water\ (CCF)$$

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.[375]

Measure Life

The measure life is assumed to be 10 years.[376]

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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[374] 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.

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

[376] 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:

$$\Delta kWH^{377} = (((((GPMbase - GPMlow) / GPMbase) * \# people * gals/day * days/year * DR) / (F/home)) * 8.3 * (TEMPft - TEMPin) / 1,000,000) / DHW Recovery Efficiency / 0.003412$$

Where:

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [378] *or actual flow rate if recorded*

---

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

[378] 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 [379]
gals/day = Average gallons per day used by faucet
= 10.9 [380]
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% [381]
F/home = Average number of faucets in the home
= 3.5 [382]
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 [383]
DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [384]
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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[379] US Energy Information Administration, Residential Energy Consumption Survey; http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc3demographics/pdf/tablehc11.3.pdf

[380] 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)

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

[382] 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

[383] 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.

[384] 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* [385]

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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[385] 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* [386]
All other variables *As above*

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

$$\Delta MMBtu = ((((2.2 - 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80-60.9) / 1,000,000) / 0.75$$

$$= 0.098\ MMBtu$$

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}[387] = 2.07 kWh * ΔWater (CCF)

---

[386] 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%.

[387] 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:

$\Delta kWh_{water} = 2.07 * 0.619$

$= 1.3$ 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.[388]

Measure Life

The measure life is assumed to be 5 years.[389]

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

[389] 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/Hr-F-ft^2)*
= *See table below. If unknown assume 1/8* [390]

Uinsul = *Overall heat transfer coefficient after addition of tank wrap (Btu/Hr-F-ft2)*
= *See table below. If unknown assume 1/18* [391]

A_{base} = *Surface area of storage tank prior to adding tank wrap (square feet)*
= *See table below. If unknown assume 23.18* [392]

---

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

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

A_{insul} = *Surface area of storage tank after addition of tank wrap (square feet)*
= *See table below. If unknown assume 25.31* [393]
ΔT = *Average temperature difference between tank water and outside air temperature (°F)*
= *60°F* [394]
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* [395]

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
50	8	18	24.99	27.06	255	0.029

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[392] 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.

[393] Ibid.

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

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

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[396], 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[397], and savings are from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kW = 234 / 8760$$

$$= 0.027 \text{ kW}$$

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[396] 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

[397] DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure will be the actual cost of installing the tank wrap. If unknown assume $35 average cost[398].

Measure Life

The measure life is assumed to be 5 years.[399]

Operation and Maintenance Impacts

n/a

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[398] Based on VEIC online product review.

[399] 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* [400]

Rnew = *R-value of existing pipe plus installed insulation*
= *Actual*

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[400] Navigant Consulting Inc., April 2009; "Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets", p77, presented to the Ontario Energy Board: http://www.oeb.gov.on.ca/OEB/_Documents/EB-2008-0346/Navigant_Appendix_C_substantiation_sheet_20090429.pdf

Length = *Length of piping insulated*
= *Actual*
Circumference = *Circumference of piping*
= *Actual (0.5" pipe = 0.13ft, 0.75" pipe = 0.196ft)*
ΔT = *Temperature difference between water in pipe and ambient air*
= *65°F* [401]
8,760 = *Hours per year*
ηDHW = *DHW Recovery efficiency (ηDHW)*
= *0.98* [402]
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:

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

---

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

[402] 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 [403]

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[404].

Measure Life

The measure life is assumed to be 15 years[405].

Operation and Maintenance Impacts

n/a

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[403] 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%

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

[405] 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_0711
Effective Date: June 2014
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 50 gallon conventional gas storage water heater rated at the federal minimum 0.58 EF[406].

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[407]:

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

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[406] The Baseline Energy Factor is based on the Federal Minimum Standard for a standard 50 gallon storage water heater. Currently this is calculated as 0.67 – (0.0019 * Rated Volume) = 0.575 EF. This ruling can be found here: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf
Please note that there is a new standard that will come in to force for water heaters sold on or after April 16 2015. This will increase the Federal standard to 0.675 – (0.0015 * Rated Volume) = 0.6 EF: http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_fedreg.pdf

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

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = MMBtuDHW * ((EFEff-EFBase)/ EFEff)$$

Where:

MMBtuDHW = *typical annual household hot water consumption (based on existing units)*
= *21.1* [408]

EF_{Base} = *Baseline Energy Factor*
= *0.575* [409]

EF_{Eff} = *Efficient Energy Factor*
= *Actual*[410]

Illustrative example – do not use as default assumption
Purchase and installation of a 0.82 gas condensing water heater:

$$\Delta MMBtu = 21.1 * ((0.82 - 0.575)/ 0.82)$$

$$= 6.3 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

---

[408] The estimate for hot water consumption for *existing* units is 23.1MMBtu, based on US EIA, Residential Energy Consumption Survey; Average Consumption for Water Heating by Major Fuels Used, 2005
http://www.eia.doe.gov/emeu/recs/recs2005/c&e/waterheating/pdf/tablewh7.pdf
VEIC estimate that the average efficiency of the existing DHW unit stock is 52.5% (based on the Federal Minimum standard from 1991 to 2001 (0.62 – (0.0019*50) = 0.525). An estimate of a new baseline unit energy consumption is therefore calculated as 23.1 * (0.525/0.575) = 21.1MMBtu.

[409] Minimum Federal Standard for a 50gallon gas fired tank; 0.67 - (0.0019 × Rated Storage Volume in gallons);
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/water_heater_fr.pdf

[410] The minimum ENERGY STAR specifications are provided above.

The incremental cost for this measure is provided below[411]:

Water Heater Type	Incremental Cost
High Efficiency Gas Storage	$175
Gas Condensing	$1,150
Whole Home Gas Tankless	$750

Measure Life

The measure life is assumed to be 13 years[412].

Operation and Maintenance Impacts

n/a

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[411] Incremental costs based on ACEEE lifecycle cost analysis; http://www.aceee.org/node/3068#lcc. High efficiency gas storage units cost $1025, condensing gas units cost $2000 and tankless units cost $1600, compared to a conventional unit cost of $850.

[412] 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_0510
Effective Date: June 2014
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 a standard electric water heater.

Definition of Efficient Condition

The efficient condition is a heat pump water heater.

Annual Energy Savings Algorithm

$$\Delta kWH = KWHbase * ((EFnew - EFbase)/EFnew) + KWHcooling - KWHheating$$

Where:

KWHbase = *Average electric DHW consumption*
= *3460* [413]

EFnew = *Energy Factor of Heat Pump water heater*
= *2.0* [414]

EFbase = *Energy Factor of standard electric water heater*
= *0.904* [415]

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[413] Assumption taken from; Residential Water Heaters Technical Support Document for the January 17, 2001, Final Rule
Table 9.3.9, p9-34,
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/09.pdf
Consistent with FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters
http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf

[414] 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

[415] As above

KWHcooling = Cooling savings from conversion of heat in home to water heat
= 61 [416]
KWHheating[417] *= Heating cost from conversion of heat in home to water heat*

KWHheating (electric resistance) = 1043
KWHheating (heat pump COP 2.0) = 521
KWHheating (fossil fuel) = 0

ΔkWH electric resistance heat = 3460 * ((2.0 – 0.904) / 2.0) + 61 - 1043
= 914 kWh
ΔkWH heat pump heat = 3460 * ((2.0 – 0.904) / 2.0) + 61 - 521
= 1436 kWh
ΔkWH fossil fuel heat = 3460 * ((2.0 – 0.904) / 2.0) + 61 - 0
= 1957 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.17 kW [418]

Annual Fossil Fuel Savings Algorithm

ΔMMBtu = -KWHheating (electric resistance) * 0.003412 / AFUEheating[419]
= -1043 *.003412 / .80
= -4.45 MMBTU[420]

---

[416] Cooling kWh= KWHbase * ((EFnew - EFbase)/EFnew)/8760 * 829 cooling hours (from TMY Baltimore data) / (SEER 10 / 3.412 BTU/Wh)

[417] Heating kWh= KWHbase * ((EFnew - EFbase)/EFnew)/8760 * 4818 cooling hours (from TMY Baltimore data) / heating system efficiency

[418] 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.

[419] 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. KWHheating (electric resistance) is that additional heating energy for a home with electric resistance heat. This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a fossil fuel heated home.

[420] Negative value because heating energy will increase due to this measure.

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $925.[421]

Measure Life

The measure life is assumed to be 10 years.[422]

Operation and Maintenance Impacts

n/a

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[421] Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005.

[422] 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

Appliance End Use

Clothes Washer*

Unique Measure Code(s): RS_LA_TOS_CWASHES_0414, RS_LA_TOS_CWASHT2_0414, RS_LA_TOS_CWASHT3_0414, RS_LA_TOS_CWASHME_0414

Effective Date: June 2014
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 2 or CEE TIER 3, ENERGY STAR Most Efficient or Top Ten minimum qualifying efficiency standards presented below:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard	>= 1.26	<= 9.5
ENERGY STAR 2011	>= 2.0	<= 6.0
CEE TIER 2	>= 2.20	<= 4.5
CEE TIER 3	>= 2.40	<= 4.0
ENERGY STAR Most Efficient (as of 1/1/2013)	>= 2.4 (for units <=2.5 ft3) >= 3.2 (for units >2.5 ft3)	<= 4.5 (for units <=2.5 ft3) <= 3.0 (for units >2.5 ft3)

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity; the higher the number, the greater the efficiency.

The Water Factor 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 condition is a clothes washer at the minimum federal baseline efficiency presented above. The average efficiency of non ENERGY STAR units available since 1/1/2011 (accounting for relatively short shelf life of products) is used to calculate savings (based on data pulled from the California Energy Commission Appliance Efficiency Database http://www.appliances.energy.ca.gov/). The average assumptions are provided below:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard	1.42	8.85

Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the ENERGY STAR, CEE TIER 2 or CEE TIER 3, ENERGY STAR Most Efficient efficiency criteria presented above. The assumed MEF and WF used in the savings algorithm are provided below[423]:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
ENERGY STAR 2011	2.0	6.0
CEE TIER 2	2.3	4.3
CEE TIER 3	2.7	3.5
ENERGY STAR Most Efficient	3.3	2.9

Annual Energy Savings Algorithm

(see 'Mid Atlantic CW Analysis_042014update.xls' for detailed calculation)

1. Calculate clothes washer savings based on Modified Energy Factor (MEF).

   The Modified Energy Factor (MEF) includes unit operation, water heating and drying energy use: "*MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E,*

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[423] For ENERGY STAR and CEE Tiers 2 and 3 the average MEF and 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 ENERGY STAR Most Efficient the average efficiency 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/)

and the energy required for removal of the remaining moisture in the wash load, D" [424].

The hot water and dryer savings calculated here assumes electric DHW and Dryer (this will be separated in Step 2).

MEFsavings = Capacity * (1/MEFbase - 1/MEFeff) * Ncycles

Where

Capacity = Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume values provided in table below[425]
MEFbase = Modified Energy Factor of baseline unit
= 1.42[426]
MEFeff = Modified Energy Factor of efficient unit
= Actual. If unknown assume average values provided below.
Ncycles = Number of Cycles per year
= 254[427]

MEFsavings is provided below based on deemed values[428]:

Efficiency Level	MEF	Capacity	MEFSavings (kWh)
Federal Standard	1.42	Assumed equal to efficient unit	0.0
ENERGY STAR	2.0	3.48	178.6
CEE Tier 2	2.3	3.47	236.0
CEE Tier 3	2.7	4.05	341.8
ENERGY STAR Most	3.3	4.26	434.4

---

[424] Definition provided on the Energy star website.

[425] Based on the average clothes washer volume of all post-1/1/2011 units from the California Energy Commission (CEC) database of Clothes Washer products. Note that we assume the baseline unit has the same capacity as the efficient unit. This is based on the assumption that customers know the capacity range that they wish to purchase and then have the options of more or less efficient units.

[426] Average MEF of post 1/1/2011, non-ENERGY STAR units from the California Energy Commission (CEC) database of Clothes Washer products.

[427] 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.

[428] See “Mid Atlantic CW Analysis_042014update.xls” for the calculation.

Efficient			

2. Break out savings calculated in Step 1 for electric DHW and electric dryer

ΔkWh = [(Capacity * 1/MEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer)] - [(Capacity * 1/MEFeff * Ncycles) * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer)]

Where:

%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[429]		
	%CW	%DHW	%Dryer
Baseline	6%	35%	59%
ENERGY STAR	7%	24%	68%
CEE Tier 2	7%	23%	70%
CEE Tier 3	9%	12%	79%
ENERGY STAR Most Efficient	10%	3%	87%
Top Ten	10%	3%	87%

%Electric_DHW = *Percentage of DHW savings assumed to be electric*

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%

---

[429] 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 “Mid Atlantic CW Analysis_042014update.xls” for the calculation.

Unknown	65%[430]

%Electric_Dryer = Percentage of dryer savings assumed to be electric

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%
Unknown	79%[431]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	178.6	114.0	80.3	15.7
CEE Tier 2	236.0	98.0	146.1	8.1
CEE Tier 3	341.8	135.2	216.8	10.2
ENERGY STAR Most Efficient	434.4	166.4	278.4	10.4

If the DHW and dryer fuel is unknown the prescriptive kWH savings based on defaults provided above should be:

	ΔkWH
ENERGY STAR	135.6
CEE Tier 2	168.8
CEE Tier 3	243.1
ENERGY STAR Most Efficient	307.7

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.

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[430] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

[431] 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.

Summer Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Assumed Run hours of Clothes Washer*
= *265* [432]

CF = *Summer Peak Coincidence Factor for measure*
= *0.029* [433]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.020	0.012	0.009	0.002
CEE Tier 2	0.026	0.011	0.016	0.001
CEE Tier 3	0.037	0.015	0.024	0.001
ENERGY STAR Most Efficient	0.048	0.018	0.030	0.001

If the DHW and dryer fuel is unknown the prescriptive kWH savings based on defaults provided above should be:

	ΔkW
ENERGY STAR	0.015
CEE Tier 2	0.018
CEE Tier 3	0.027
ENERGY STAR Most Efficient	0.034

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:

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[432] 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.

[433] Ibid.

ΔMMBtu = [(Capacity * 1/MEFbase * Ncycles) * ((%DHWbase * %Natural Gas_DHW * R_eff) + (%Dryerbase * %Gas _Dryer)] - [(Capacity * 1/MEFeff * Ncycles) * ((%DHWeff * %Natural Gas_DHW * R_eff) + (%Dryereff * %Gas_Dryer)] * MMBtu_convert

Where:

R_eff = Recovery efficiency factor
= 1.26[434]
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%
Unknown	35%[435]

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	6%[436]

Other factors as defined above

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

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[434] 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.

[435] 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.

[436] 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.

	ΔMMBtu			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.00	0.3	0.3	0.6
CEE Tier 2	0.00	0.6	0.3	0.9
CEE Tier 3	0.00	0.9	0.4	1.3
ENERGY STAR Most Efficient	0.00	1.2	0.5	1.7

If the DHW and dryer fuel is unknown the prescriptive MMBtu savings should be:

	ΔMMBtu
ENERGY STAR	0.12
CEE Tier 2	0.23
CEE Tier 3	0.34
ENERGY STAR Most Efficient	0.44

Annual Water Savings Algorithm

$$\Delta Water\ (CCF) = (Capacity * (WFbase - WFeff)) * Ncycles$$

Where

WFbase = *Water Factor of baseline clothes washer*
= *8.85*[437]

WFeff = *Water Factor of efficient clothes washer*
= *Actual. If unknown assume average values provided below.*

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below[438]:

---

[437] Average MEF of post 1/1/2011, non-ENERGY STAR units.

[438] 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/)

Efficiency Level	WF	ΔWater (CCF per year)
Federal Standard	8.85	0.0
ENERGY STAR	6.0	3.4
CEE Tier 2	4.3	5.4
CEE Tier 3	3.5	7.4
ENERGY STAR Most Efficient	2.9	8.6

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}[439] $= 2.07\ kWh * \Delta Water\ (CCF)$

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below:

Efficiency Level	ΔkWh_{water}
ENERGY STAR	7.0
CEE Tier 2	11.1
CEE Tier 3	15.2
ENERGY STAR Most Efficient	17.8

Incremental Cost

The incremental cost for this measure is provided in the table below[440]:

Efficiency Level	Incremental

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[439] 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.

[440] Based on weighting (top v front loader) the average incremental costs derived in "2010-2012 WA017 Ex Ante Measure Cost Study Draft Report", Itron, February 28,2014. Note that ENERGY STAR Most Efficient cost is extrapolated from other data points. See "Mid Atlantic CW Analysis_042014update.xls" for the calculation.

	Cost
ENERGY STAR	$53
CEE Tier 2	$127
CEE Tier 3	$136
ENERGY STAR Most Efficient	$183

Measure Life

The measure life is assumed to be 14 years [441].

Operation and Maintenance Impacts

n/a

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[441] 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_0414, RS_LA_ RTR_CWASHT2_0414, RS_LA_ RTR_CWASHT3_0414, RS_LA_ RTR_CWASHME_0414

Effective Date: June 2014
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 2 or CEE TIER 3, ENERGY STAR Most Efficient minimum qualifying efficiency standards presented below.

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard	>= 1.26	<= 9.5
ENERGY STAR 2011	>= 2.0	<= 6.0
CEE TIER 2	>= 2.20	<= 4.5
CEE TIER 3	>= 2.40	<= 4.0
ENERGY STAR Most Efficient (as of 1/1/2013)	>= 2.4 (for units <=2.5 ft3) >= 3.2 (for units >2.5 ft3)	<= 4.5 (for units <=2.5 ft3) <= 3.0 (for units >2.5 ft3)

The modified energy factor (MEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity; the higher the number, the greater the efficiency.

The Water Factor 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[442], 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.

To estimate the efficiency of the existing unit, the Federal Standard for clothes washers prior to 2004 is used; 0.817 MEF[443]. The Water Factor is assumed to be 11.0[444]

The new baseline unit is consistent with the Time of Sale measure and is based on the average efficiency of the post 1/1/2011[445] non-ENERGY STAR units available (based on data pulled from the California Energy Commission Appliance Efficiency Database http://www.appliances.energy.ca.gov/).

The baseline assumptions are provided below:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Existing unit	0.817	11.0
Federal Standard	1.42	8.85

Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the ENERGY STAR, CEE TIER 2 or CEE TIER 3 or ENERGY STAR Most Efficient efficiency criteria presented above. The assumed MEF and WF used in the savings algorithm are provided below[446]:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
ENERGY STAR 2011	2.0	6.0

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[442] Based on 1/3 of the measure life.

[443] http://www.cee1.org/resid/seha/rwsh/press-rel.php3

[444] US DOE, Life Cycle Cost Model, spreadsheet dated December 1999, indicates 38.61 gallons of water per cycle. Assume average size of 3.5 cu ft gives 11.0 WF assumption. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls

[445] 1/1/2007 is when the current 1.26 MEF Federal Standard became effective.

[446] For ENERGY STAR and CEE Tiers 2 and 3 the average MEF and 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 ENERGY STAR Most Efficient the average efficiency 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/)

CEE TIER 2	2.3	4.3
CEE TIER 3	2.7	3.5
ENERGY STAR Most Efficient	3.3	2.9

Annual Energy Savings Algorithm
(see 'Mid Atlantic CW Retrofit Analysis_042014update.xls' for detailed calculation)

1. Calculate clothes washer savings based on Modified Energy Factor (MEF).

   The Modified Energy Factor (MEF) includes unit operation, water heating and drying energy use: *"MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D"* [447].

   The hot water and dryer savings calculated here assumes electric DHW and Dryer (this will be separated in Step 2).

   MEFsavings = Capacity * (1/MEFbase - 1/MEFeff) * Ncycles

Where

Capacity = Clothes Washer capacity (cubic feet)
= Actual. If capacity is unknown assume values provided in table below[448]
MEFbase = Modified Energy Factor of baseline unit
Remaining life of existing unit (first 5 years) = *0.817*[449]
Remaining measure life (next 9 years) = *1.42*[450]

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[447] Definition provided on the Energy star website.

[448] Based on the average clothes washer volume of all post-1/1/2011 units from the California Energy Commission (CEC) database of Clothes Washer products. Note that we assume the baseline unit has the same capacity as the efficient unit. This is based on the assumption that customers know the capacity range that they wish to purchase and then have the options of more or less efficient units.

[449] The Federal baseline for clothes washers prior to 2004 is used; 0.817 MEF.

[450] Average MEF of post 1/1/2011, non-ENERGY STAR units from the California Energy Commission (CEC) database of Clothes Washer products.

MEFeff = Modified Energy Factor of efficient unit
= Actual. If unknown assume average values provided below.
Ncycles = Number of Cycles per year
= 254[451]

MEFsavings is provided below based on deemed values[452]:

Efficiency Level	MEF	Capacity	MEFSavings (kWh)	
			Remaining life of existing unit (first 5 years)	Remaining measure life (next 9 years)
Existing unit	0.817	Assumed equal to efficient unit	n/a	n/a
Federal Standard	1.42		n/a	n/a
ENERGY STAR	2.0	3.48	639.4	178.6
CEE Tier 2	2.3	3.47	696.3	236.0
CEE Tier 3	2.7	4.05	879.0	341.8
ENERGY STAR Most Efficient	3.3	4.26	998.9	434.4

2. Break out savings calculated in Step 1 for electric DHW and electric dryer

ΔkWh = [(Capacity * 1/MEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer)] - [(Capacity * 1/MEFeff * Ncycles) * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer)]

Where:

%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[453]

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[451] 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.

[452] See “Mid Atlantic CW Retrofit Analysis_042014update.xls” for the calculation.

	%CW	%DHW	%Dryer
Existing and Baseline	6%	35%	59%
ENERGY STAR	7%	24%	68%
CEE Tier 2	7%	23%	70%
CEE Tier 3	9%	12%	79%
ENERGY STAR Most Efficient	10%	3%	87%

%Electric_DHW = *Percentage of DHW savings assumed to be electric*

DHW fuel	%Electric_DHW
Electric	100%
Fossil Fuel	0%
Unknown	65%[454]

%Electric_Dryer = *Percentage of dryer savings assumed to be electric*

Dryer fuel	%Electric_Dryer
Electric	100%
Fossil Fuel	0%
Unknown	79%[455]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Remaining life of existing unit (first 5 years):

ΔkWH			
Electric DHW Electric	Gas DHW Electric	Electric DHW Gas Dryer	Gas DHW Gas Dryer

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[453] 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 “Mid Atlantic CW Retrofit Analysis_042014update.xls” for the calculation.

[454] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

[455] 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.

	Dryer	Dryer		
ENERGY STAR	639.4	406.7	274.0	41.4
CEE Tier 2	696.3	390.4	339.6	33.7
CEE Tier 3	879.0	476.5	442.7	40.2
ENERGY STAR Most Efficient	998.9	525.0	515.7	41.8

Remaining measure life (next 9 years):

	ΔkWH			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	178.6	114.0	80.3	15.7
CEE Tier 2	236.0	98.0	146.1	8.1
CEE Tier 3	341.8	135.2	216.8	10.2
ENERGY STAR Most Efficient	434.4	166.4	278.4	10.4

If the DHW and dryer fuel is unknown the prescriptive kWH savings based on defaults provided above should be:

	ΔkWH		Equivalent Mid Life Savings Adjustment (after 5 years)	Equivalent Weighted Average Annual Savings[456]
	Remaining life of existing unit (first 5 years)	Remaining measure life (next 9 years)		
ENERGY STAR	482.0	135.6	28.1%	287.1
CEE Tier 2	514.9	168.8	32.8%	320.1
CEE Tier 3	647.1	243.1	37.6%	419.8
ENERGY STAR Most Efficient	732.2	307.7	42.0%	493.4

Summer Coincident Peak kW Savings Algorithm

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[456] 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 14 year annual savings values and finding the equivalent annual savings that produces the same result. The Real Discount Rate of 5.0% is used.

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

Where:

Hours = *Assumed Run hours of Clothes Washer*
= *265* [457]
CF = *Summer Peak Coincidence Factor for measure*
= *0.029* [458]

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Remaining life of existing unit (first 5 years):

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.070	0.045	0.030	0.005
CEE Tier 2	0.076	0.043	0.037	0.004
CEE Tier 3	0.096	0.052	0.048	0.004
ENERGY STAR Most Efficient	0.109	0.057	0.056	0.005

Remaining measure life (next 9 years):

	ΔkW			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.020	0.012	0.009	0.002
CEE Tier 2	0.026	0.011	0.016	0.001
CEE Tier 3	0.037	0.015	0.024	0.001
ENERGY STAR Most Efficient	0.048	0.018	0.030	0.001

If the DHW and dryer fuel is unknown the prescriptive kWH savings based on defaults provided above should be:

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[457] 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.

[458] Ibid.

	ΔkW		Equivalent Mid Life Savings Adjustment (after 5 years)	Equivalent Weighted Average Annual Savings
	Remaining life of existing unit (first 5 years)	Remaining measure life (next 9 years)		
ENERGY STAR	0.053	0.015	28.1%	0.031
CEE Tier 2	0.056	0.018	32.8%	0.035
CEE Tier 3	0.071	0.027	37.6%	0.046
ENERGY STAR Most Efficient	0.080	0.034	42.0%	0.054

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:

$$\Delta \text{MMBtu} = [(\text{Capacity} * 1/\text{MEFbase} * \text{Ncycles}) * ((\%\text{DHWbase} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryerbase} * \%\text{Gas \_Dryer})] - [(\text{Capacity} * 1/\text{MEFeff} * \text{Ncycles}) * ((\%\text{DHWeff} * \%\text{Natural Gas\_DHW} * \text{R\_eff}) + (\%\text{Dryereff} * \%\text{Gas\_Dryer})] * \text{MMBtu\_convert}$$

Where:

R_eff = *Recovery efficiency factor*
= *1.26*[459]

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%
Unknown	35%[460]

---

[459] 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.

[460] Default assumption for unknown fuel is based on percentage of homes with gas DHW from

%Gas_Dryer = Percentage of dryer savings assumed to be Natural Gas

Dryer fuel	%Gas_Dryer
Electric	0%
Natural Gas	100%
Unknown	6%[461]

Other factors as defined above

Using the default assumptions provided above, the prescriptive savings for each configuration are presented below.

Remaining life of existing unit (first 5 years):

	ΔMMBtu			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.00	1.00	1.25	2.25
CEE Tier 2	0.00	1.32	1.22	2.53
CEE Tier 3	0.00	1.73	1.49	3.22
ENERGY STAR Most Efficient	0.00	2.04	1.65	3.69

Remaining measure life (next 9 years):

	ΔMMBtu			
	Electric DHW Electric Dryer	Gas DHW Electric Dryer	Electric DHW Gas Dryer	Gas DHW Gas Dryer
ENERGY STAR	0.00	0.28	0.34	0.61
CEE Tier 2	0.00	0.59	0.31	0.90
CEE Tier 3	0.00	0.89	0.43	1.31
ENERGY STAR Most Efficient	0.00	1.15	0.53	1.69

If the DHW and dryer fuel is unknown the prescriptive MMBtu savings should be:

ΔMMBtu	Equivalent Mid	Equivalent

EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic States.

[461] 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.

	Remaining life of existing unit (first 5 years)	Remaining measure life (next 9 years)	Life Savings Adjustment (after 5 years)	
ENERGY STAR	0.43	0.12	27.6%	0.25
CEE Tier 2	0.54	0.23	42.5%	0.36
CEE Tier 3	0.70	0.34	48.5%	0.50
ENERGY STAR Most Efficient	0.82	0.44	53.7%	0.60

Annual Water Savings Algorithm

$$\Delta Water\ (CCF) = (Capacity * (WFbase - WFeff)) * Ncycles$$

Where

WFbase = *Water Factor of baseline clothes washer*

Remaining life of existing unit (first 5 years) = *11.0*[463]

Remaining measure life (next 9 years) = *8.85*[464]

WFeff = *Water Factor of efficient clothes washer*

= *Actual. If unknown assume average values provided below.*

Using the default assumptions provided above, the prescriptive water savings for each efficiency level are presented below[465]:

Efficiency Level	WF	ΔWater	Equivalent	Equivalent

---

[462] 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 14 year annual savings values and finding the equivalent annual savings that results in the same result. The Real Discount Rate of 5.0% is used.

[463] US DOE, Life Cycle Cost Model, spreadsheet dated December 1999, indicates 38.61 gallons of water per cycle. Assume average size of 3.5 cu ft gives 11.0 WF assumption. http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/lcc_spreadsheet.xls

[464] Average MEF of post 1/1/2011, non-ENERGY STAR units.

[465] 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/)

		(CCF per year)		Mid Life Savings Adjustment (after 5 years)	Weighted Average Annual Savings[466]
		Remaining life of existing unit (first 5 years)	Remaining measure life (next 9 years)		
Existing Unit	11.0	n/a	n/a		
Federal Standard	8.85	n/a	n/a		
ENERGY STAR	6.0	5.9	3.4	56.6%	4.5
CEE Tier 2	4.3	7.9	5.4	67.6%	6.5
CEE Tier 3	3.5	10.4	7.4	71.0%	8.7
ENERGY STAR Most Efficient	2.9	11.8	8.6	73.2%	10.0

Incremental Cost

The full measure cost assumption is provided below[467]:

Efficiency Level	Full Measure Cost
ENERGY STAR	$570
CEE Tier 2	$644
CEE Tier 3	$653
ENERGY STAR Most Efficient	$700

The deferred (for 5 years) baseline replacement clothes washer cost is assumed to be $517.

Measure Life

The measure life is assumed to be 14 years [468].

Operation and Maintenance Impacts

n/a

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[466] 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 14 year annual savings values and finding the equivalent annual savings that results in the same result. The Real Discount Rate of 5.0% is used.

[467] Based on weighting (top v front loader) the average costs derived in “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28,2014. Note that ENERGY STAR Most Efficient cost is extrapolated from other data points. See “Mid Atlantic CW Retrofit Analysis_042014update.xls” for the calculation.

[468] 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

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)[469] 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)[470]
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[471] as defined below:

Capacity (pints/day)	ENERGY STAR Criteria (L/kWh)
<75	≥1.85
75 to ≤185	≥2.80

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[469] Energy Star Version 3.0 became effective 10/1/12

[470] 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

[471] 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 [472]
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:

Capacity	Capacity Used	Federal Standard Criteria	ENERGY STAR Criteria	Annual kWh		
				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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[472] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

> 54 to ≤ 75	65	1.7	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*[473]
CF = *Summer Peak Coincidence Factor for measure*
= *0.37* [474]

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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[473] 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

[474] 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[475].

Measure Life

The measure life is assumed to be 12 years. [476]

Operation and Maintenance Impacts

n/a

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[475] 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

[476] ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

ENERGY STAR Air Purifier/Cleaner*

Unique Measure Code(s): RS_AP_TOS_AIRPUR_0414
Effective Date: June 2014
End Date: TBD

Measure Description

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of a baseline model.

Definition of Baseline Condition

The baseline equipment is assumed to be a conventional non-ENERGY STAR unit with consumption estimates based upon EPA research on available models, 2011[477].

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[478] 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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[477] ENERGY STAR Appliance Savings Calculator; http://www.energystar.gov/buildings/sites/default/uploads/files/appliance_calculator.xlsx?7224-046c=&7224-__046ceiling_fan_calculator_xlsx=&a0f2-2e6f&a0f2-2e6f

[478] 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[479]

= see table below

kWh_{ESTAR} = ENERGY STAR kWh consumption per year[480]

= see table below

Clean Air Delivery Rate (CADR)	CADR used in calculation	Baseline Unit Energy Consumption (kWh/year)	ENERGY STAR Unit Energy Consumption (kWh/year)	ΔkWH
CADR 51-100	75	441	148	293
CADR 101-150	125	733	245	488
CADR 151-200	175	1025	342	683
CADR 201-250	225	1317	440	877
CADR Over 250	275	1609	537	1072

Summer Coincident Peak kW Savings Algorithm

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

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[479] 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.

[480] 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[481]

CF = Summer Peak Coincidence Factor for measure

= 0.67[482]

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.[483]

Measure Life

The measure life is assumed to be 9 years[484].

Operation and Maintenance Impacts

There are no operation and maintenance cost adjustments for this measure.[485]

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[481] Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

[482] Assumes appliance use is equally likely at any hour of the day or night.

[483] ENERGY STAR Appliance Savings Calculator; EPA research on available models, 2012

[484] ENERGY STAR Appliance Savings Calculator; Based on Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

[485] 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.

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[486]. 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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[486] 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 $CFM_{Natural}$*[487]
= *dependent on exposure level:*

Exposure	*Well Shielded*	*24*
	Normal	*20*
	Exposed	*18*

CDH = *Cooling Degree Hours*[488]
= *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*[489]
= *0.75*

0.018 = *The volumetric heat capacity of air (Btu/ft3°F)*

ηCool = *Efficiency in SEER of Air Conditioning equipment*
= *actual. If not available use*[490]*:*

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[487] 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

[488] 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)

[489] 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.

Age of Equipment	*SEER Estimate*
Before 2006	*10*
After 2006	*13*

LM = *Latent Multiplier*
= *6.9*[491]

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.

$$\Delta kWh = [(((3{,}400 - 2{,}250) / 24) * 60 * 7{,}514 * 0.75 * 0.018) / 1{,}000 / 12] * 6.9$$

$$= 168 \text{ kWh}$$

<u>Heading savings for homes with electric heat (Heat Pump or resistance):</u>

$$\Delta kWh = ((((CFM50Exist - CFM50New) / N\text{-}factor) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat) * 293.1$$

Where:
N-factor = *conversion from* CFM_{50} *to* $CFM_{Natural}$[492]
= *Based on building height and exposure level:*

	# Stories:	1	1.5	2	3
Exposure	Well Shielded	24	21.6	19.2	16.8

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[490] 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.

[491] 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.

[492] 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

	Normal	20	18	16	14
	Exposed	18	16.2	14.4	12.6

HDD = *Heating Degree Days*
= *dependent on location*[493]

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*[494]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*[495]
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.

$$\Delta kWh = [(((3{,}400 - 2{,}250) / 24) * 60 * 24 * 3{,}275 * 0.018) / 1{,}000{,}000 / 2.5] * 293.1$$

477 kWh

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[493] 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.

[494] 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.

[495] 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* [496]
Baltimore, MD	*542* [497]
Washington, DC	*681*

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

= *0.69* [498]

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* [499]

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

<u>For homes with Fossil Fuel Heating:</u>

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[496] 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)

[497] 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.

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

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

$$\Delta MMBTU = (((CFM50Exist - CFM50New) / N\text{-}factor) * 60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$$

Where:

N-factor = *conversion from CFM_{50} to $CFM_{Natural}$*[500]

= *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*[501]

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*[502]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[503]*.*

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[500] 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

[501] 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.

[502] 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.

[503] 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

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.

$$\Delta MMBtu = (((3,400 - 2,250) / 24) * 60 * 24 * 3,275 * 0.018) / 1,000,000 / 0.7$$

$$= 5.8\ MMBtu$$

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[504].

Operation and Maintenance Impacts

n/a

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envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

[504] 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[505]. 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:

$$\Delta kWh = ((1/Rexist - 1/Rnew) * CDH * DUA * Area) / 1{,}000 / \eta Cool$$

Where:

---

[505] 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.

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*[506]
= *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*[507]
= *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*[508]*:*

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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[506] 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/)

[507] 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.

[508] 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*[509]

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*[510]*:*

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.

$$\Delta kWh = (((1/5 - 1/30) * 3457 * 24 * 1{,}200) / 1{,}000{,}000 / 2.5) * 293.1$$

$$= 1{,}945 \text{ kWh}$$

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[509] The 10 year average annual heating degree day value is calculated for a number of locations, using a balance point for heating equipment use of 60 degrees (based on data obtained from http://academic.udayton.edu/kissock/http/Weather/citylistUS.htm). The 60 degree balance point is used based on a PRISM evaluation of approximately 600,000 Ohio residential single family customers showing this is the point below which heating is generally used.

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

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* [511]
Baltimore, MD	*542* [512]
Washington, DC	*681*

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

= *0.69* [513]

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* [514]

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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[511] 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)

[512] 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.

[513] 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.

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

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1,000,000 / \eta Heat$$

Where:

HDD = *Heating Degree Days*
= *dependent on location*[515]

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*[516]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[517]*.*

Illustrative example – do not use as default assumption
Insulating 1200 square feet of attic from R-5 to R-30 in a home with a 75% efficiency heating system in Baltimore, MD.

$$\Delta MMBtu = ((1/5 - 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 0.75$$

$$= 22 \text{ MMBtu}$$

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[515] 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.

[516] 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.

[517] 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[518].

Operation and Maintenance Impacts

n/a

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[518] 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 [519]

Heating kWh Savings (Electric Resistance) = 356 kWh per 100 square feet window area

Heating kWh Savings (Heat Pump COP 2.0) = 194 kWh per 100 square feet window area

Cooling kWh Savings (SEER 10) = 205 kWh per 100 square feet window area

Summer Coincident Peak kW Savings Algorithm

$$\Delta kWcooling = \Delta kWREM * CF$$

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[519] Based on REMRate modeling of New Jersey baseline existing home moved to Baltimore climate with electric furnace or air source heat pump HSPF 2.0, SEER 10 AC. Ducts installed in un-conditioned basement. Duct leakage set at RESNET/HERS qualitative default.

Where:

$\Delta kWREM$ = *Delta kW calculated in REMRate model*
= *0.12 kW per 100 square feet window area*

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [520]

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* [521]

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.[522]

Measure Life

The measure life is assumed to be 25 years.[523]

Operation and Maintenance Impacts

n/a

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[520] 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.

[521] 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.

[522] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007.

[523] 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

$$\Delta kWh = kWh_{Base} - kWh_{Two\ Speed}$$ [524]

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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[524] 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

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [525]

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[526]
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[527]

$$\Delta kW_{SSP} = (1.3-0.171) * 0.20$$

$$= 0.23 \text{ kW}$$

$$\Delta kW_{SSP} = (1.3-0.171) * 0.27$$

$$= 0.31 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[525] 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

[526] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[527] Ibid.

The incremental cost for this measure is assumed to be $175 for a two speed pool pump motor[528].

Measure Life

The measure life is assumed to be 10 yrs[529].

Operation and Maintenance Impacts

n/a

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[528] Based on review of Lockheed Martin pump retail price data, July 2009.
[529] 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

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}$$ [530]

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*

$$\Delta kWh = 707 - 113$$

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[530] 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

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [531]

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*[532]
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*[533]

$$\Delta kW_{SSP} = (1.3\text{-}0.087) * 0.20$$

$$= 0.24\ kW$$

$$\Delta kW_{SSP} = (1.3\text{-}0.\ 087) * 0.27$$

$$= 0.34\ kW$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $750 for a variable speed pool pump motor[534].

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[531] 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

[532] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[533] Ibid.

Measure Life

The measure life is assumed to be 10 yrs[535].

Operation and Maintenance Impacts

n/a

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[534] Based on review of Lockheed Martin pump retail price data, July 2009.
[535] 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[536]

$Weighting_{Office}$ = Relative penetration of computers

= 41%[537]

kWh_{Ent} = Estimated energy savings from using an APS in a home entertainment system

= 75.1 kWh[538]

$Weighting_{Ent}$ = Relative penetration of televisions

= 59%[539]

ISR = In service rate

= 83.2%[540]

$$\Delta kWh = (31 * 41\% + 75.1 * 59\%) * 83.2$$

$$= 47.4 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

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[536] 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.

[537] EmPower 2012 Residential Retrofit evaluation

[538] NYSERDA 2011, Advanced Power Strip Research Report

[539] EmPower 2012 Residential Retrofit evaluation

[540] 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*[541]

CF = *Coincidence Factor*
= *0.8*[542]

$$\Delta kW = (47.4/6{,}351) * 0.8$$
$$= 0.0060\ kW$$

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[543].

Measure Life

The measure life is assumed to be 4 years[544].

Operation and Maintenance Impacts

n/a

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[541] EmPower 2012 Residential Retrofit evaluation

[542] Ibid

[543] NYSERDA 2011, Advanced Power Strip Research Report

[544] 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_0614
Effective Date: June 2014
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 an incandescent/halogen light bulb meeting the standards described in the Energy Independence and Security Act of 2007.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

Version 4 of this TRM introduces a new methodology for calculating the delta watts in this lighting measure; lumen equivalence. This method may be used as an alternative to the existing “Delta Watts Multiplier” method. The lumen equivalence method requires the user to determine the bulb type, wattage, and lumen rating of the efficient bulb and find a baseline bulb with equivalent lumens. Since this methodology requires a change to the implementation of these measures and a potential burden on utilities, the existing and new methodologies are both provided below. A single methodology should be used for all measures in a particular utility or program to prevent the potential implication of claiming whichever methodology provides higher savings.

Delta Watts Multiplier Method:

$$\Delta kWh = ((CFLwatts * DeltaMultiplier) / 1000) * HOURS * ISR * WHFe$$

Where:

CFLwatts = *CFL Lamp Watts (if known)*

DeltaMultiplier = *Multiplier to calculate delta watts. Depends upon bulb wattage and year of replacement*[545]

CFL Wattage	Delta Watts Multiplier
	2014 and Beyond
15 or less	1.83
16-20	1.79
21W+	1.84

If Compact Fluorescent Watts is unknown use 25.1[546] *as the delta watts (i.e., for (CFLwatts x DeltaMultiplier)).*

Note: See below for remaining variables

Lumen Equivalence Method:

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBase = *Based on lumens of CFL bulb*[547]:

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[545] Average wattage of compact fluorescent from *RLW study* was 15.5W, and the replacement incandescent bulb was 61.2W. This is a ratio of 3.95 to 1, and the delta watts is equal to the compact fluorescent bulb multiplied by 2.95: RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009. Post EISA multipliers are calculated by finding the new delta watts after incandescent bulb wattage is reduced (from 100W to 72W in 2012, 75W to 53W in 2013 and 60W to 43W in 2014); see MidAtlantic CFL Adjustments.xls. Note from 2014 on all wattages listed are subject to EISA and therefore are a lower delta watts multiplier.

[546] To account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below. Calculated by dividing 45.7W (delta between 61.2W and 15.5W from RLW study referenced above) by the average 2014 "Delta Watts Multiplier" from table.

[547] Base wattage is based upon the post first phase of EISA wattage.

Minimum Lumens	Maximum Lumens	$\text{Watts}_{\text{Base}}$
5280	6209	300
3000	5279	200
2601	2999	150
1490	2600	72
1050	1489	53
750	1049	43
310	749	29
250	309	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.*[548]

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

= *1.00* [549]

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

Delta Watts Multiplier Method:

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[548] 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.

[549] 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.

A 19W CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory in 2014:

ΔkWh = ((19 * 1.79) / 1000) * 2,969 * 1.00 * 1.10

= 111 kWh

Lumen Equivalence Method:
A 19W, 1,200 lumen CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory in 2014

ΔkWh = ((53 - 19) / 1000) * 2,969 * 1.00 * 1.10

= 111 kWh

Summer Coincident Peak kW Savings Algorithm

Delta Watts Multiplier Method:

ΔkW = ((CFLwatts * DeltaMultiplier) / 1000) * ISR * WHFd * CF

Lumen Equivalence Method:

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

Delta Watts Multiplier Method:

A 19W CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kWh = ((19 * 1.79) / 1000) * 1.00 * 1.32 * 0.69$$

$$= 0.03 \text{ kW}$$

Lumen Equivalence Method:
A 19W, 1,200 lumen CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = ((53 - 19) / 1000) * 1.00 * 1.32 * 0.69$$

$$= 0.03 \text{ kW}$$

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 [550]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [551]

0.75 = Assumed heating system efficiency [552]

For example, assuming a 19W CFL is purchased and installed in a conditoned office building with gas heat in BGE service territory in 2014:

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[550] 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.

[551] 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).

[552] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

$\Delta MMBTU = -108 * 0.00065$

$= -0.07$ MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

For the Retail (Time of Sale) measure, the incremental capital cost is \$1.80 from June 2014[553].

Measure Life

The measure life by building type is presented in the table below.[554]

Building Type	Measure Life (Years)
Grocery	1.4
Health	2.6
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 CFL Adjustments.xls). The key assumptions used in this calculation are documented below:

	Standard	Efficient

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

[554] Measure life calculated by building type as "10,000/HOURS" where 10,000 is the average lifetime of General Purpose Replacement, CFL-type ENERGY STAR Certified Light Bulbs ("ENERGY STAR Certified Light Bulbs," Accessed on May 1, 2014, <https://data.energystar.gov/Government/ENERGY-STAR-Certified-Light-Bulbs/8qjd-zcsy?>)

	Incandescent	Incandescent
Replacement Cost	\$0.50	\$1.40[555]
Component Life (Hours)	1,000[556]	1,000[557]

The calculated net present value of the baseline replacement costs for CFL type and installation year are presented below[558]:

Building Type	NPV of Baseline Replacement Costs
Grocery	\$6.17
Health	\$9.37
Office	\$10.02
Other	\$8.67
Retail	\$8.67
School	\$9.96
Warehouse/ Industrial	\$8.60
Unknown	\$9.37

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

[556] Assumes rated life of incandescent bulb of 1,000 hours.

[557] 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 1,000 hours (as provided by G. Arnold, Optimal Energy and confirmed by N. Horowitz at NRDC).

[558] Note, these values have been adjusted by the appropriate In Service Rate (1.00). See ‘MidAtlantic CFL adjustments’ for more information. The discount rate used for these calculations is 5.0%.

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 light 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 T8 lamps and ballasts. The list is updated frequently and is available at http://library.cee1.org/content/commercial-lighting-qualifying-products-lists.

For time of sale or new construction, this measures assumes that a HPT8 or RWT8 fixture is installed instead of a standard performance 4-ft T8 fixture. 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.

Two-foot and 3-ft T8 advanced T8 systems can similarly replace standard-performance 2-ft and 3-ft T8 or T12 systems. Although 2-ft and 3-ft lamps are not listed on the CEE website, the same qualifying ballasts listed on the website that are used for 4-ft lamps should be selected for the 2-ft and 3-ft lamps.

Definition of Baseline Condition

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) and any applicable codes and standards in the region. 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 85W.

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.*[559]

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

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[559] 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.

= *1.00*[560]

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:

ΔkWh = ((89 - 72) / 1000) * 2,969 * 1.00 * 1.10

= 56 kWh per fixture

Retrofit:

ΔkWh = ((136 - 72) / 1000) * 2,969 * 1.00 * 1.10

= 209 kWh per fixture

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*

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

= *See table "C&I Interior Lighting Coincidence Factors by Building Type" in Appendix D.*

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* [561]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [562]
0.75 = *Assumed heating system efficiency* [563]

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[561] 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.

[562] 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).

[563] 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 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.[564]

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.[565]

Measure Life for Retrofit Measures with T12 Baseline

Year	2014	2015	2016	2017
Measure Life	5.0	4.6	4.3	No T12 baseline

Operation and Maintenance Impacts

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[564] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[565] 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.
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.
If a customer relamped an existing fixture with T12s the day the standard takes 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. Note: Adjusted measures lives take into account the savings that would result over the duration of the unadjusted measure life relative to baseline T8 fixtures once T12s are no longer available.

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:[566]

Illustrative examples – do not use as default assumption

Retrofit[567]

	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
Component Life[568] (years)	5.71[569]	20[570]	8.57[571]	20[572]

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	$30	$7.67	$47.50
Component Life[573] (years)	5.71[574]	20[575]	8.57[576]	20[577]

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[566] Unless otherwise noted, all table values adapted from Efficiency Vermont Technical Reference Manual 2013-82.5, August 2013.

[567] While the retrofit example assumes a baseline T12 system, 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 when relamping/reballasting is necessary due to federal standards.

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

[569] Assumes baseline lamp with rated life of 20,000 hours operated for 3,500 hours annually.

[570] Assumes baseline ballast with rated life of 70,000 hours operated for 3,500 hours annually.

[571] Assumes efficient lamp with rated life of 30,000 hours operated for 3,500 hours annually.

[572] Assumes efficient ballast with rated life of 70,000 hours operated for 3,500 hours annually.

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

[574] Assumes baseline lamp with rated life of 20,000 hours operated for 3,500 hours annually.

The calculated net present value of the net replacement costs by market are presented below[578]:

Application	NPV of Net Replacement Costs 2014
Retrofit	$22.35
Time of Sale or New Construction	$1.88

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[575] Assumes baseline ballast with rated life of 70,000 hours operated for 3,500 hours annually.

[576] Assumes efficient lamp with rated life of 30,000 hours operated for 3,500 hours annually.

[577] Assumes efficient ballast with rated life of 70,000 hours operated for 3,500 hours annually.

[578] 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 after 40,000 hours.

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.[579]

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

= 1.00 [580]

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[579] 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.

[580] 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.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00065$$

Where:

0.7 = Aspect ratio [581]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [582]

0.75 = Assumed heating system efficiency [583]

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:

$$\Delta MMBTU = -902.6 * 0.00065$$

$$= -0.59 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $300.[584]

Measure Life

The measure life is assumed to be 15 years.[585]

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[581] 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.

[582] 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).

[583] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[584] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

Operation and Maintenance Impacts

n/a

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[585] '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.[586]
WattsEE = Actual Connected load of LED exit sign
HOURS = Average hours of use per year
= 8,760 [587]
ISR = In Service Rate or percentage of units rebated that get installed
= 1.00 [588]

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[586] 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.

[587] Assumes operation 24 hours per day, 365 days per year.

[588] 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* [589]

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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[589] 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.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75
= -ΔkWh * 0.00065

Where:

0.7 = Aspect ratio [590]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [591]

0.75 = Assumed heating system efficiency [592]

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:

ΔMMBTU = -106 * 0.00065

= -0.069 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $35.[593]

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[590] 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.

[591] 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).

[592] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[593] Represents the full installed cost of an LED exit sign. LED exit signs can typically be purchased for ~$25 (see http://www.exitlightco.com/Exit_Signs and "http://www.simplyexitsigns.com"). Assuming replacing exit sign requires 15 minutes of a

Measure Life

The measure life is assumed to be 7 years.[594]

Operation and Maintenance Impacts

	Baseline
	CFL
Replacement Cost	$12[595]
Component Life (years)	1.14[596]

The calculated net present value of the baseline replacement costs are presented below[597]:

Baseline	NPV of Baseline Replacement Costs
	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.

[594] 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.

[595] 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.

[596] 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.

[597] 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_0614 and CI_LT_RTR_SSLDWN_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of an ENERGY STAR qualified commercial LED recessed downlight in place of a standard efficiency lighting technology[598]. This measure could be either a time of sale, new construction, or retrofit installation.

Definition of Baseline Condition

The baseline condition is a standard efficiency downlight technology such as incandescent, compact fluorescent, or metal halide.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR Program Requirements for Luminaires v1.1 qualified commercial LED recessed downlight listed on the ENERGY STAR Qualified Light Fixtures list[599].

Annual Energy Savings Algorithm

For time of sale or new construction installations:

$$\Delta kWh = ((WattsEE * (WattsBASE_{typ}/WattsEE_{typ}) - WattsEE) / 1000) * ISR * HOURS * WHF_e$$

$$= (((WattsEE * 3.08) - WattsEE) / 1000) * ISR * HOURS * WHF_e$$

For retrofit installations:

$$\Delta kWh = ((WattsBASE – WattsEE) / 1000) * ISR * HOURS * WHF_e$$

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[598] See http://www.energystar.gov/ia/partners/product_specs/program_reqs/Final_Luminaires_Program_Requirements.pdf?495a-8afe

[599] The list can be found here: http://downloads.energystar.gov/bi/qplist/Light%20Fixtures%20Product%20List.xls?204b-8496

Where:

WattsEE = *Connected load of LED recessed downlight*
= *Actual Installed [W]*
WattsBASE$_{typ}$ = *typical baseline wattage; assumed as 54.8W*[600]
WattsEE$_{typ}$ = *typical wattage of the LED recessed downlight; assumed as 17.8W*[601]
WattsBASE = *Connected load of the baseline light fixture*
= *Actual Installed [W]*
ISR = *1.00*[602]
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.*[603]
WHF$_e$ = *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

$$\Delta kW = ((WattsBASE - WattsEE) / 1{,}000) * ISR * WHF_d * CF$$

Where:

WHF$_d$ = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*

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[600] Based on 2008-2010 Efficiency Vermont historical data of 835 installed measures

[601] Based on 2008-2010 Efficiency Vermont historical data of 835 installed measures

[602] 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.

[603] 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.

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.

$$\Delta MMBTU = (-\Delta kWh\ /\ WHFe) * Aspect\ Ratio * 0.003413 * Heating\ Fraction\ /\ \eta_{Heat}$$

$$= -\Delta kWh * 0.00065$$

Where:

Aspect Ratio = 0.70[604]
0.003413 = MMBtu/kWh unit conversion factor
Heating Fraction (lighting heat that contributes to space heating) = 0.23[605]
η_{Heat} *= 0.75*[606]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $80[607] for time of sale or new construction installations. Custom incremental costs should be calculated for retrofit installations.

Measure Life

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[604] 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.

[605] 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).

[606] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[607] Efficiency Vermont Technical Reference User Manual No. 2010-67a

The measure life is assumed to be 10 years[608].

Operation and Maintenance Impacts

There are significant operation and maintenance savings associated with this measure. If the actual existing or baseline system component costs are unknown, use the following composite baseline component assumptions to calculate the O&M impacts[609]:

Assume 40% 26W Compact Fluorescent System

Lamp Life (hours): 10,000
Lamp Cost: $9.70
Lamp Rep. Labor Cost: $2.67
Lamp Rep. Recycle Cost: $0.25
Ballast Life (hours): 40,000
Ballast Cost: $16.00
Ballast Rep. Labor Cost: $25.00
Ballast Rep. Disposal Cost: $5.00

Assumed 60% Halogen PAR30/38

Lamp Life (hours): 2,500
Lamp Cost: $10.00
Lamp Rep. Labor Cost: $2.67

The calculated net present value of the baseline replacement costs, assuming a weighted average of 40% CFL and 60% halogen baselines, is $93.45.[610]

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[608] 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).

[609] Efficiency Vermont Technical Reference User Manual No. 2010-67a

[610] 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.*[611]
WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

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[611] 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* [612]
0.003413 *= Constant to convert kWh to MMBTU*
0.23 *= Fraction of lighting heat that contributes to space heating* [613]
0.75 *= Assumed heating system efficiency* [614]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $10.8 per fixture.[615]

Measure Life

The measure life is assumed to be 15 years.[616]

Operation and Maintenance Impacts

Delamping reduces the number of periodic lamp replacements required, saving $1.25/year.

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[612] 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.

[613] 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).

[614] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[615] 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.

[616] 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.[617]

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[617] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

SVGe = *Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
= *0.28*[618]

ISR = *In Service Rate or percentage of units rebated that get installed*
= *1.00*[619]

WHFe = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and 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*[620]

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

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

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

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 [621]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [622]

0.75 = Assumed heating system efficiency [623]

Annual Water Savings Algorithm

n/a

Incremental Cost

The 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.[624]

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[621] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[622] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[623] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

Measure Life

The measure life is assumed to be 10 years.[625]

Operation and Maintenance Impacts

n/a

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[624] 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.

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

Daylight Dimming Control*

Unique Measure Code(s): CI_LT_TOS_DDIM_0614
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.[626]

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[626] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

SVG = *Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
= 0.28 [627]

ISR = *In Service Rate or percentage of units rebated that get installed*
= 1.00 [628]

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[629]

$$\Delta kW = kWconnected \times SVG \times ISR \times WHFd \times CF$$

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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[627] Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. "Lighting Controls in Commercial Buildings." The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180.

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

[629] As a conservative assumption, the peak demand savings algorithm assumes the same annual savings factor (SVG) as the energy savings equation. It is probable that higher than average availability of daylight coincides with summer peak periods. This factor is a candidate for future study as increased accuracy will likely lead to increased peak demand savings estimates.

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 [630]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [631]

0.75 = Assumed heating system efficiency [632]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $100 per ballast controlled for both fixture-mounted and remote-mounted daylight sensors.[633]

Measure Life

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[630] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

[631] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[632] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[633] Northeast Energy Efficiency Partnerships Incremental Cost Study Report, Navigant, 2011. Assumes the simple average of cost of all photosensors types. Source does not differentiate costs between fixture and remote-mounted sensors.

The measure life is assumed to be 10 years.[634]

Operation and Maintenance Impacts

n/a

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

Advanced Lighting Design - Commercial

Unique Measure Code(s): CI_LT_TOS_ADVLTNG_0614
Effective Date: June 2014
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 the Maryland Building Performance Standards, Chapter 76 (2012 International Energy Conservation Code), Title 17 of the Delaware Code (2009 International Energy Conservation Code), and District of Columbia Construction Codes Supplement of 2008 (2006 International Energy Conservation Code). Because each jurisdiction has adopted unique lighting power density requirements, this measure entry presents three different baseline conditions to be used in each of the three relevant jurisdictions. For completeness, the lighting power density requirements for both the Building Area Method and the Space-by-Space Method are presented.[635]

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[635] Energy code lighting power density requirements can generally be satisfied by using one of two methods. The Building Area Method simply applies a blanket LPD requirement to 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.

Definition of Efficient Condition

The efficient condition assumes lighting systems that achieve lighting power densities below the maximum lighting power densities required by the relevant jurisdictional energy codes as described above. Actual site lighting power densities should be determined on a case-by-case basis.

Annual Energy Savings Algorithm[636]

$$\Delta kWh = ((LPDBASE – LPDEE) / 1000) * AREA * HOURS * WHFe$$

Where:

LPDBASE = Baseline lighting power density for building or space type (W/ft^2). See tables below for values by jurisdiction and method.

Building Area Method Baseline LPD Requirements by Jurisdiction[637]

	Lighting Power Density (W/ft^2) by Region		
Building Area Type	**Washington, D.C.**	**Delaware**	**Maryland**
Automotive Facility	0.9	0.9	0.9
Convention Center	1.2	1.2	1.2
Court House	1.2	1.2	1.2
Dining: Bar Lounge/Leisure	1.3	1.3	1.3
Dining: Cafeteria/Fast Food	1.4	1.4	1.4
Dining: Family	1.6	1.6	1.6
Dormitory	1.0	1.0	1.0
Exercise Center	1.0	1.0	1.0
Fire Station	1.0	1.0	0.8
Gymnasium	1.1	1.1	1.1

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[636] If the Space-by-Space Method is used, the total energy savings will be the sum of the energy savings for each individual space type.

[637] IECC 2006, Table 505.5.2; IECC 2009, Table 505.5.2; ASHRAE 90.1-2007, Table 9.5.1; IECC 2012, Table C405.5.2(1). Note that the Maryland 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. For convenience, the LPD are provided in Excel format in the “Mid-Atlantic TRM LPD Tables.xlsx” worksheet.

	Lighting Power Density (W/ft^2) by Region		
Building Area Type	**Washington, D.C.**	**Delaware**	**Maryland**
Healthcare-Clinic	1.0	1.0	1.0
Hospital	1.2	1.2	1.2
Hotel	1.0	1.0	1.0
Library	1.3	1.3	1.3
Manufacturing Facility	1.3	1.3	1.3
Motel	1.0	1.0	1.0
Motion Picture Theatre	1.2	1.2	1.2
Multi-Family	0.7	0.7	0.7
Museum	1.1	1.1	1.1
Office	1.0	1.0	0.9
Parking Garage	0.3	0.3	0.3
Penitentiary	1.0	1.0	1.0
Performing Arts Theatre	1.6	1.6	1.6
Police Station	1.0	1.0	1.0
Post Office	1.1	1.1	1.1
Religious Building	1.3	1.3	1.3
Retail	1.5	1.5	1.4
School/University	1.2	1.2	1.2
Sports Arena	1.1	1.1	1.1
Town Hall	1.1	1.1	1.1
Transportation	1.0	1.0	1.0
Warehouse	0.8	0.8	0.6
Workshop	1.4	1.4	1.4

Space-by-Space Method Baseline LPD Requirements by Jurisdiction[638]

	Lighting Power Density (W/ft^2) by Region		
Common Space Types	**Washington, D.C.**	**Delaware**	**Maryland**
Atrium	N/A	N/A	N/A
First Three Floors	0.6	0.6	N/A
Each Additional Floor	0.2	0.2	N/A
First 40 feet in height	N/A	N/A	0.03 per ft. ht.
Above 40 feet in height	N/A	N/A	0.02 per ft. ht.
Audience/Seating Area	0.9	0.9	N/A
For Auditorium	N/A	N/A	0.9
For Performing Arts Theater	2.6	2.6	2.6
For Motion Picture Theater	1.2	1.2	1.2
Classroom/Lecture/Training	1.4	1.4	1.3
Conference/Meeting/Multipurpose	1.3	1.3	1.2
Corridor/Transition	N/A	N/A	0.7
Corridor/Transition	0.5	0.5	N/A
Dining Area	0.9	0.9	N/A
For Bar Lounge/Leisure Dining	1.4	1.4	1.4
For Family Dining	2.1	2.1	1.4
Dressing/Fitting Room Performing Arts Theater	N/A	N/A	1.1
Dressing/Locker/Fitting Room	0.6	0.6	N/A
Electrical/Mechanical	1.5	1.5	1.1

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[638] ASHRAE 90.1-2007. Table 9.6.1; IECC 2012, Table C405.5.2(2). Note that the Maryland energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2010, Table 9.6.1. As the IECC 2012 requirements are less stringent they are presented here. To provide a clear, uniform presentation of requirements, the tables from the respective energy codes have been restructured. An "N/A" for a given space type indicates that no requirement is presented for that space type in that jurisdiction's energy code. For convenience, the LPD are provided in Excel format in the "Mid-Atlantic TRM LPD Tables.xlsx" worksheet.

Food Preparation	1.2	1.2	1.2
Laboratory	1.4	1.4	N/A
For Classrooms	N/A	N/A	1.3
For Medical/Industrial/Research	N/A	N/A	1.8
Lobby	1.3	1.3	1.1
For Elevator	N/A	N/A	N/A
For Performing Arts Theater	3.3	3.3	3.3
For Motion Picture Theater	1.1	1.1	1
Locker Room	N/A	N/A	0.8
Lounge/Recreation	1.2	1.2	0.8
Office	N/A	N/A	N/A
Enclosed	1.1	1.1	1.1
Open Plan	1.1	1.1	1
Restrooms	0.9	0.9	1
Sales Area	1.7	1.7	1.6
Stairs – Active	0.6	0.6	0.7
Storage	N/A	N/A	0.8
Active	0.8	0.8	N/A
Inactive	0.3	0.3	N/A
Workshop	1.9	1.9	1.6
Building Specific Space-By-Space Types			
Automobile	N/A	N/A	N/A
Service/Repair	0.7	0.7	0.7
Bank/Office	N/A	N/A	N/A
Banking Activity Areas	1.5	1.5	1.5
Convention center	N/A	N/A	N/A
Audience/Seating Area	0.7	0.7	0.9
Exhibit Space	1.3	1.3	1.5

Court House/Police Station/Penitentiary	N/A	N/A	N/A
Courtroom	1.9	1.9	1.9
Confinement Cells	0.9	0.9	1.1
Judges' Chambers	1.3	1.3	1.3
Penitentiary Audience/Seating Area	0.7	0.7	0.5
Penitentiary Classroom/Lecture/Training	1.3	1.3	1.3
Penitentiary Dining Area	1.3	1.3	1.1
Dormitory	N/A	N/A	N/A
Living Quarters	1.1	1.1	1.1
Fire Stations	N/A	N/A	N/A
Engine Room	0.8	0.8	0.8
Sleeping Quarters	0.3	0.3	0.3
Gymnasium/Exercise Center	N/A	N/A	N/A
Exercise Area	0.9	0.9	0.9
Exercise Center Audience/Seating Area	0.3	0.3	N/A
Gymnasium Audience/Seating Area	0.4	0.4	0.4
Playing Area	1.4	1.4	1.4
Hospital	N/A	N/A	N/A
Active Storage	0.9	0.9	N/A
Corridor/Transition	1.0	1.0	1.0
Emergency	2.7	2.7	2.7
Exam/Treatment	1.5	1.5	1.7
Laundry-Washing	0.6	0.6	0.6
Lounge/Recreation	0.8	0.8	0.8
Medical Supply	1.4	1.4	1.4
Nursery	0.6	0.6	0.9
Nurses' Station	1.0	1.0	1.0
Operating Room	2.2	2.2	2.2
Patient Room	0.7	0.7	0.7

Pharmacy	1.2	1.2	1.2
Physical Therapy	0.9	0.9	0.9
Public and Staff Lounge	N/A	N/A	0.8
Radiology	0.4	0.4	1.3
Recovery	0.8	0.8	1.2
Hotel/Motel	N/A	N/A	N/A
Dining Area	1.3	1.3	1.3
Guest Rooms	1.1	1.1	1.1
Lobby	1.1	1.1	2.1
Motel Dining Area	1.2	1.2	1.2
Motel Guest Rooms	1.1	1.1	1.1
Library	N/A	N/A	N/A
Card File and Cataloging	1.1	1.1	1.1
Reading Area	1.2	1.2	1.2
Stacks	1.7	1.7	1.7
Manufacturing	N/A	N/A	N/A
Control Room	0.5	0.5	N/A
Corridor/Transition	0.5	0.5	0.4
Detailed Manufacturing	2.1	2.1	1.3
Equipment Room	1.2	1.2	1.0
Extra High Bay (>50 ft. Floor to Ceiling Height)	N/A	N/A	1.1
High Bay (≥ 25 ft. Floor to Ceiling Height)	1.7	1.7	1.2
Low Bay (< 25 ft. Floor to Ceiling Height)	1.2	1.2	1.2
Museum	N/A	N/A	N/A
General Exhibition	1.0	1.0	1.0
Inactive Storage	0.8	0.8	N/A
Restoration	1.7	1.7	1.7
Parking Garage	N/A	N/A	N/A
Garage Area	0.2	0.2	0.2

Post Office	N/A	N/A	N/A
Sorting Area	1.2	1.2	0.9
Religious Buildings	N/A	N/A	N/A
Audience/Seating Area	1.7	1.7	2.4
Fellowship Hall	0.9	0.9	0.6
Worship Pulpit, Choir	2.4	2.4	2.4
Retail	N/A	N/A	N/A
Dressing/Fitting Area	N/A	N/A	0.9
Mall Concourse	1.7	1.7	1.6
Sales Area	1.7	1.7	1.6
Sports Arena	N/A	N/A	N/A
Audience/Seating Area	0.4	0.4	0.4
Court Sports Arena	2.3	2.3	N/A
Court Sports Area - Class 4	N/A	N/A	0.7
Court Sports Area - Class 3	N/A	N/A	1.2
Court Sports Area - Class 2	N/A	N/A	1.9
Court Sports Area - Class 1	N/A	N/A	3.0
Indoor Playing Field Area	1.4	1.4	N/A
Ring Sports Arena	2.7	2.7	2.7
Transportation	N/A	N/A	N/A
Airport/Train/Bus - Baggage Area	1.0	1.0	1.0
Airport – Concourse	0.6	0.6	0.6
Audience/Seating Area	0.5	0.5	N/A
Terminal - Ticket Counter	1.5	1.5	1.5
Warehouse	N/A	N/A	N/A
Fine Material Storage	1.4	1.4	1.4
Medium/Bulky Material Storage	0.9	0.9	0.6

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.[639]

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 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:

$$\Delta kWh = ((1.0 - 0.75) / 1000) * 15{,}000 * 2{,}969 * 1.10$$

$$= 12{,}247 \text{ kWh}$$

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

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[639] 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.

= *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:

$$\Delta kWh = ((1.0 - 0.75) / 1000) * 15,000 * 1.32 * 0.69$$

$$= 3.42 \text{ kW}$$

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* [640]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [641]
0.75 = *Assumed heating system efficiency* [642]

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:

$$\Delta kWh = -12,247 * 0.00065$$

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[640] 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.

[641] 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).

[642] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

= 7.96 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.[643]

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of the efficient and baseline replacement components, there may be significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs should be estimated on a case-by-case basis.

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[643] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf. Assumes Advanced Lighting Design lifetime will be consistent with that of the "Fluorescent Fixture" measure from the reference document. This measure life assumes that the most common implementation of this measure will be for new construction or major renovation scenarios where new fixtures are installed. In such cases, adopting the fixture lifetime for the LPD reduction measure seems most appropriate.

LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting

Unique Measure Code(s): CI_LT_TOS_LEDODPO_0614 and CI_LT_RTR_LEDODPO_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of an LED outdoor pole/arm- or wall-mounted luminaire for parking lot, street, or general area illumination in place of a high-intensity discharge light source. Eligible applications include new construction and time of sale 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. For the purposes of this characterization, standard metal halide fixtures are the assumed baseline technology.

Definition of Efficient Condition

The efficient condition is defined as an LED outdoor pole/arm- or wall-mounted luminaire. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List[644].

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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[644] DesignLights Consortium Qualified Products List <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

= 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 based on the appropriate baseline description.

Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage[645]

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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[645] 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* [646]*. Otherwise, use site specific annual operating hours information.*[647]

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* [648]

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

= 0 kW

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[646] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[647] 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.

[648] It is assumed that efficient outdoor area lighting, when functioning properly, will never result in coincident peak demand savings.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[649]

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.[650]

Operation and Maintenance Impacts[651]

Due to differences in costs and lifetimes of fixture components between the efficient and baseline cases, there are significant operation and

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[649] Efficiency Maine Technical Reference User Manual No.2010-1, 2010.

[650] The average rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 11/21/2012 <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php> is approximately 70,000 hours. For the purposes of this characterization, it is assumed the typical equipment will operate for 60,000 hours. Assuming average annual operating hours of 3,338 (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 18 years.

[651] 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.

maintenance impacts associated with this measure. Estimated O&M savings and the component cost and lifetime assumptions are presented in the table below.

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*

Unique Measure Code(s): CI_LT_TOS_LEDHB_0614 and CI_LT_RTR_LEDHB_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of an LED high-bay luminaire for general area illumination in place of a high-intensity discharge or fluorescent light source. Eligible applications include new construction and time of sale luminaires installed at a minimum height of 20 feet. Because of the improved optical control afforded by LED luminaires, 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).

Illustrative examples – do not use as default assumption

For illustrative purposes, the baseline is assumed to be a 250W pulse start metal halide fixture delivering 16,000 mean system lumens.

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[652].

Illustrative examples – do not use as default assumption

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[652] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

For illustrative purposes the high efficiency condition is an LED luminaire drawing 178W.[653]

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE = Actual Connected load of baseline fixture

WattsEE = Actual Connected load of the LED fixture

HOURS = Average hours of use per year

= If annual operating hours are unknown, see table “C&I Interior Lighting Operating Hours by Building Type” in Appendix D. Otherwise, use site specific annual operating hours information.[654]

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

= 1.00 [655]

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 metal halide fixture is replaced with an LED fixture in a warehouse with gas heat in BGE service territory in 2014:

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[653] 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.

[654] 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.

[655] 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.

ΔkWh = ((288 - 178) / 1000) * 4,116 * 1.00 * 1.02

= 462 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 250W metal halide fixture is replaced with an LED fixture in a warehouse with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

ΔkW = ((288 - 178) / 1000) * 1.00 * 1.24 * 0.72

= 0.10 kW

Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75
= -ΔkWh * 0.00065

Where:

0.7 = *Aspect ratio* [656]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [657]
0.75 = *Assumed heating system efficiency* [658]

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.[659]

Measure Life

The measure life is assumed to be 16 years.[660]

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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[656] 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.

[657] 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).

[658] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[659] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013.

[660] The average rated lifetime for applicable products on the DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL> is approximately 64,000 hours. Assuming average annual operating hours of 4,009 for a typical warehouse lighting application, the estimated measure life is 16 years.

LED 1x4, 2x2, and 2x4 Luminaires*

Unique Measure Code(s): CI_LT_TOS_LED1x4_0614, CI_LT_TOS_LED2x2_0614, CI_LT_TOS_LED2x4_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of an LED 1x4, 2x2, or 2x4 luminaire for general area illumination in place of a fluorescent light source. These luminaires 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 new construction and time of sale applications.. Because of the improved optical control afforded by LED luminaires, 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 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).

Illustrative examples – do not use as default assumption

For illustrative purposes, the assumed baseline scenarios are as follows:

1x4 Luminaire: 4ft F32 T8 2-Lamp fixture with electronic ballast delivering 4,600 mean system lumens.

2x2 Luminaire: 2ft FB32 U-Tube T8 2-Lamp fixture with electronic ballast delivering 4,100 mean system lumens.

2x4 Luminaire: 4ft F32 T8 3-Lamp fixture with electronic ballast delivering 6,900 mean system lumens.

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[661].

Illustrative examples – do not use as default assumption

For illustrative purposes[662], the assumed high efficiency scenarios are as follows:

1x4 Luminaire: LED luminaire drawing 43W.
2x2 Luminaire: LED luminaire drawing 39W.
2x4 Luminaire: LED luminaire drawing 70W.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR * WHFe$$

Where:

WattsBASE	*= Actual Connected load of baseline fixture*
WattsEE	*= Actual Connected load of the LED fixture*
HOURS	*= Average hours of use per year* *= If annual operating hours are unknown, see table "C&I Interior Lighting Operating Hours by Building Type" in Appendix D.*[663] *Otherwise, use site specific annual operating hours information.*[664]
ISR	*= In Service Rate or percentage of units rebated that get installed* *= 1.00* [665]

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[661] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[662] 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.

[663] 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.

[664] 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.

[665] 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

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 the illustrative 1x4 example, a 4ft F32 T8 2-Lamp fixture with electronic ballast is replaced with an LED fixture in a conditoned office building with gas heat in BGE service territory in 2014:

$$\Delta kWh = ((53 - 43) / 1000) * 2,969 * 1.00 * 1.10$$

$$= 32.7 \text{ kWh}$$

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 the illustrative 1x4 example, a 4ft F32 T8 2-Lamp fixture with electronic ballast is replaced with an LED fixture in a conditoned office building with gas

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the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

heat in BGE service territory in 2014 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 [666]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [667]

0.75 = Assumed heating system efficiency [668]

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 examples, the incremental costs are approximately $100 for 1x4, $75 for 2x2, and $125 for 2x4 luminaires.[669]

Measure Life

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[666] 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.

[667] 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).

[668] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[669] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013.

The measure life is assumed to be 16 years.[670]

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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[670] The average rated lifetime for applicable products on the DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL> is approximately 59,000 hours. Assuming average annual operating hours of 3,642 for a typical office lighting application, the estimated measure life is 16 years.

LED Parking Garage/Canopy Lighting – Commercial

Unique Measure Code(s): CI_LT_TOS_LEDODPG_0614 and CI_LT_RTR_LEDODPG_0614
Effective Date: June 2014
End Date: TBD

Measure Description

This measure relates to the installation of an LED parking garage or canopy fixture in place of a high-intensity discharge light source. Eligible applications include new construction and time of sale applications.

Definition of Baseline Condition

The baseline condition is defined as an parking garage or canopy fixture with a high intensity discharge light-source. Typical baseline technologies include metal halide (MH) and high pressure sodium (HPS) lamps.

Illustrative examples – do not use as default assumption

For the purposes of this characterization, standard metal halide fixtures are the assumed baseline technology.

Definition of Efficient Condition

The efficient condition is defined as an LED parking garage or canopy fixture. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List[671]. If the product is not approved by DesignLights Consortium, WattsEE values may be assigned based upon fixture rating as obtained from the corresponding LM-79 test report.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) * HOURS * ISR$$

Where:

WattsBASE = Actual Connected load of baseline fixture

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[671] DesignLights Consortium Qualified Products List <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

= If the actual baseline fixture wattage is unknown, use the default values presented in the "Parking Garage or Canopy Fixture Baseline and Efficient Wattage" table below.

WattsEE = Actual Connected load of the LED fixture

= If the actual LED fixture wattage is unknown, use the default values presented in the "Parking Garage or Canopy Fixture Baseline and Efficient Wattage" table below based on the based on the appropriate baseline description.

Parking Garage or Canopy Fixture Baseline and Efficient Wattage[672]

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

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[672] 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.

Measure Category	Baseline Description	WattsBASE	Efficient Description	WattsEE
LED Parking Garage/Canopy Fixture replacing 251 and above HID	251W and above base HID	452	DLC Qualified LED Parking Garage and Canopy Luminaires	248

HOURS = *Average hours of use per year*

= *If annual operating hours are unknown, assume 3,338 for canopy applications and 8,760 for parking garage applications*[673]*. Otherwise, use site specific annual operating hours information.*[674]

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

= *1.00* [675]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage 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*

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[673] 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.

[674] 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.

[675] 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.

= 0 for canopy applications and 1.0 for parking garage applications [676]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage metal halide fixture is replaced with an LED fixture:

$$\Delta kW = ((288 - 162) / 1000) * 1.00 * 1.00$$

$$= 0.13 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[677]

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.[678]

Operation and Maintenance Impacts[679]

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[676] 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.

[677] Efficiency Maine Technical Reference User Manual No.2010-1, 2010.

[678] The average rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 11/21/2012 <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php> exceeds 80,000 hours. 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.

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.

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

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[679] 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.

Heating Ventilation and Air Conditioning (HVAC) End Use

High Efficiency Unitary AC

Unique Measure Code(s): CI_HV_TOS_UNIA/C_0614
Effective Date: June 2014
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. This measure applies to time of sale and new construction opportunities.

Definition of Baseline Condition

The baseline condition is a split or packaged unitary air conditioning system meeting minimum efficiency standards as presented in the 2009 International Energy Conservation Code (IECC 2009) (see table “Baseline and Efficient Efficiency Levels by Unit Capacity” below)[680].

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[681] efficiency standards as defined below (see table “Baseline and Efficient Levels by Unit Capacity” below).

Baseline and Efficient Levels by Unit Capacity

Equipment Type	Size Category	Subcategory	Baseline Condition (IECC 2009)	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

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[680] Integrated Energy Efficiency Ratio (IEER) requirements have been incorporated from ASHRAE 90.1-2007, “Energy Standard for Buildings Except Low-Rise Residential Buildings”, 2008 Supplement. IECC 2009 does not present IEER requirements.

[681] 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 2009)	Efficient Condition (CEE Tier 1)	Efficient Condition (CEE Tier 2)
	≥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

For units with capacities less than 65,000 Btu/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$$\Delta kWh = (Btu/hour/1000) * ((1/SEERBASE - 1/SEEREE)) * HOURS$$

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:

$$\Delta kWh = (Btu/hour/1000) * ((1/EERBASE - 1/EEREE)) * HOURS$$

Where:

Btu/hour = *Size of equipment in Btu/hour*
= *Actual Installed*
SEEREE = *SEER Efficiency of efficient unit*
= *Actual Installed*
SEERBASE = *SEER Efficiency of baseline unit*
= *Based on IECC 2009 for the installed capacity. See table above.*
EEREE = *EER Efficiency of efficient unit*
= *Actual Installed*
EERBASE = *EER Efficiency of baseline unit*
= *Based on IECC 2009 for the installed capacity. See table above.*
HOURS = *Full load cooling hours*

= 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[682]

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

$$\Delta kW = (Btu/hour/1000) * ((1/EERBASE - 1/EEREE)) * CF$$

Where:

EERbase = *EER Efficiency of baseline unit*
= *Based on IECC 2009 for the installed capacity. See table above.*

EERee = *EER Efficiency of efficient unit*
= *Actual installed*

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[682] 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.

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[683]

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[684]

For example, a 5 ton unit with EER rating of 12 installed in Baltimore estimating PJM summer peak coincidence:[685]

$$\Delta kW = (60{,}000/1000) * (1/10.8 - 1/12) * 0.360$$

$$= 0.20 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost[686]

Size Category	Efficient Condition (CEE Tier 1)[687]	Efficient Condition (CEE Tier 2)[688]
<=65,000 Btu/h	$100/ton	$140/ton
>65,000 Btu/h	$120/ton	$160/ton

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

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

[685] Assumes baseline unit with 13 SEER converted to EER using the following estimate: EER = SEER/1.2

[686] 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.

[687] Based on personal communication with VT equipment distributors and a review of Cost Values and Summary Documentation for 2008 Database for Energy-Efficient Resources, California Public Utilities Commission.

[688] CEE Tier 2 incremental costs are estimated by multiplying the ratio of the incremental costs for CEE Tier 2 and Tier 1 units from the NEEP Incremental Cost Study, Navigant, 2011, by the incremental cost estimates for Tier 1. This estimate should be revisited in the future once adequate program data is collected.

Measure Life

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

Variable Frequency Drive (VFD) for HVAC*

Unique Measure Code(s): CI_MO_RTR_VFDRIVE_0614,
Effective Date: June 2014
End Date: TBD

Measure Description

This measure defines savings associated with installing a Variable Frequency Drive on a motor of 15 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, 15 hp or less, without a VFD control.

Definition of Efficient Condition

The efficient condition is a motor, 15 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[690]

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
Industrial - 2 Shift	4,730	2,120	5,376
Industrial - 3 Shift	6,631	2,805	5,376

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[690] United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8th Edition for 2013 Program Year. Orange, CT.

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[691]

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[691] 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.

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)*[692]

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):

$$\Delta kW = ((10 * 0.746 * 0.75)/ 0.9) * 0.466 * 0.28$$

$$= 0.81 \text{ kW}$$

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[692] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives – Pumps.

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[693]

Motor Horsepower (HP)	Total Installed Costs
5	$2,125
15	$3,193

Measure Life

The measure life is assumed to be 15 years for HVAC applications.[694]

Operation and Maintenance Impacts

n/a

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[693] United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8th Edition for 2013 Program Year. Orange, CT.

[694] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

Electric Chillers*

Unique Measure Code: CI_HV_TOS_ELCHIL_0614, CI_HV_RTR_ELCHIL_0614, Effective Date: June 2014 End Date: TBD

Measure Description

This measure relates to the installation of a new high-efficiency electric water chilling package in place of a standard efficiency electric water chilling package. This measure applies to time of sale and new construction opportunities.

Definition of Baseline Condition

Time of Sale or New Construction: The baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2009 (IECC 2009), Table 503.2.3(7).[695]

Definition of Efficient Condition

The efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2009 (IECC 2009), Table 503.2.3(7).

Annual Energy Savings Algorithm

$$\Delta kWh = TONS * (IPLVbase - IPLVee) * HOURS$$

Where:

TONS	*= Total installed capacity of the water chilling package[tons]* *= Actual Installed*
IPLVbase	*= Integrated Part Load Value (IPLV)*[696] *of the baseline equipment [kW/ton]*

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[695] Current Washington, D.C. commercial energy code is based on IECC 2009. Current Delaware commercial energy code is based on ASHRAE 90.1-2007; specifically, current chiller requirements are presented in Addendum M. Current Maryland commercial energy code is based on IECC 2012. In all cases, the water chilling package minimum efficiency requirements are identical. For simplicity, only the requirements in IECC 2009 are referenced in this measure entry.

[696] Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

= *For time of sale: Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below*[697]

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.*

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = TONS * (Full\_Loadbase - Full\_Loadee) * CF$$

Where:

Full_Loadbase = *Full load efficiency of the baseline equipment [kW/ton]*
= *For time of sale: Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below*[698]

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*[699]

CF_{SSP} = *Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= *0.923*[700]

Annual Fossil Fuel Savings Algorithm

n/a

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[697] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

[698] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

[699] 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.

[700] 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 water-cooled chillers are assumed to be custom. For air-cooled chillers, see "Air-Cooled Chiller Incremental Costs" table below.

Air-Cooled Chiller Incremental Costs ($/Ton)[701]

Capacity (Tons)	Efficient Air-Cooled Chiller Full Load EER			
	9.9	10.2	10.52	10.7
50	$229	$457	$701	$838
100	$114	$229	$350	$419
150	$76	$152	$234	$279
200	$47	$93	$143	$171
400	$23	$47	$71	$85

Measure Life

The measure life is assumed to be 23 years[702].

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency[703]

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,	<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

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[701] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

[702] 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"

[703] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

Equipment Type	Size Category	Units	Path A[a]		Path B[a]	
			Full Load	IPLV	Full Load	IPLV
Positive Displacement	≥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 2009 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[704]

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/ economizer	752	781	836	777	897	833	952
Community College	CAV w/o economizer	1,010	1,048	1,121	1,044	1,202	1,117	1,274
Community College	VAV w/ economizer	585	607	649	605	695	647	736
High School	CAV w/ economizer	428	440	463	439	489	462	511
High School	CAV w/o economizer	819	830	851	829	875	850	896
High School	VAV w/ economizer	306	316	336	315	359	335	379
Hospital	CAV w/ economizer	1,307	1,341	1,406	1,338	1,479	1,403	1,543
Hospital	CAV w/o economizer	2,094	2,135	2,213	2,130	2,302	2,210	2,379
Hospital	VAV w/ economizer	1,142	1,165	1,208	1,162	1,257	1,206	1,300

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[704] 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.**
Hotel	CAV w/ economizer	2,972	2,972	2,971	2,972	2,971	2,971	2,971
Hotel	CAV w/o economizer	3,166	3,165	3,163	3,165	3,161	3,163	3,159
Hotel	VAV w/ economizer	2,953	2,958	2,967	2,957	2,977	2,966	2,986
Large Retail	CAV w/ economizer	987	1,011	1,057	1,009	1,109	1,055	1,155
Large Retail	CAV w/o economizer	1,719	1,730	1,750	1,729	1,772	1,749	1,792
Large Retail	VAV w/ economizer	817	838	877	835	921	875	959
Office Building	CAV w/ economizer	700	710	729	709	750	728	768
Office Building	CAV w/o economizer	2,162	2,193	2,252	2,189	2,318	2,249	2,377
Office Building	VAV w/ economizer	670	685	716	684	749	714	779
University	CAV w/ economizer	796	822	871	819	925	868	974
University	CAV w/o economizer	1,103	1,135	1,198	1,132	1,267	1,194	1,329
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

$$\Delta \text{MMBtu} = \text{CAP} * \text{HOURS} * (1/\text{EFF}_{\text{base}} - 1/\text{EFF}_{\text{ee}}) / 1{,}000{,}000$$

Where:

CAP = *Equipment capacity [Btu/h]*
= *Actual Installed*
HOURS = *Full Load Heating Hours*

= See "Heating Full Load Hours" table in the "Reference Tables" section below[705]

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[706]

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[707].

Operation and Maintenance Impacts

n/a

Reference Tables

Time of Sale Baseline Equipment Efficiency[708]

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[705] 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.

[706] 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.

[707] Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

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[709]

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
1,300	$4,047	$6,499	E_t

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[708] Baseline efficiencies based on current federal standards: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf.

[709] 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.

1,500	$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

Heating Full Load Hours[710]

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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[710] 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_0614, CI_HV_RTR_GASFUR_0614
Effective Date: June 2014
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[711]

ΔkWh = 733 kWh[712]

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.19 kW[713]

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = CAP * HOURS * ((1/AFUE_{base}) - (1/AFUE_{ee})) / 1,000,000$$

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[711] Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

[712] 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.

[713] Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.

Where:

CAP = Capacity of the high-efficiency equipment [Btu/h]
= Actual Installed
HOURS = Full Load Heating Hours
= See "Heating Full Load Hours" table in the "Reference Tables" section below[714]
$AFUE_{base}$ *= Annual Fuel Utilization Efficiency of the baseline equipment*
= For time of sale: 0.80[715]
$AFUE_{ee}$ *= 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 assumed to be $0.009 per Btu/h[716].

Measure Life

The measure life is assumed to be 18 years[717].

Operation and Maintenance Impacts

n/a

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[714] 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.

[715] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(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. The baseline unit is non-condensing.

[716] Incremental Cost based on analysis of proprietary vendor data from models from Gibson and Frigadaire, and from DOE "Energy Conservation Program for Certain Industrial Equipment: Test Procedures and Energy Conservation Standards for Commercial Heating, Air-Conditioning, and Water Heating Equipment Final Rule Technical Support Document". September 14, 2009.

[717] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, "http://www.ctsavesenergy.org/files/Measure Life Report 2007.pdf"

Reference Tables

Heating Full Load Hours[718]

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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[718] 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. 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[719]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0 \text{ kW}$$ [720]

Annual Fossil Fuel Savings Algorithm

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[719] 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.

[720] Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

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[721]

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[722].

Operation and Maintenance Impacts

n/a

Reference Tables

Savings Factors[723]

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

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[721] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

[722] General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

[723] kWh/ton savings from NY Standard Approach Model, with scaling factors based on enthalpy data from NYC and Mid-Atlantic cities.

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

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[724].

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) * 365$$

Where:

kWhBASEdailymax [725] = *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 [726] = *See table below.*

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[724] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 2.1, ENERGY STAR, January 2008.

[725] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[726] 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	≤ 0.250V + 1.250
15 ≤ V < 30	≤ 0.400V – 1.000
30 ≤ V < 50	≤ 0.163V + 6.125
50 ≤ V	≤ 0.158V + 6.333
Glass Door Cabinets	
0 < V < 15	≤ 0.607V + 0.893
15 ≤ V < 30	≤ 0.733V – 1.000
30 ≤ V < 50	≤ 0.250V + 13.500
50 ≤ V	≤ 0.450V + 3.500
Chest Configuration	
Solid or Glass Door Cabinets	≤ 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 [727]
CF = Summer Peak Coincidence Factor for measure
= 0.772 [728]

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[727] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[728] 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 [729]

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.[730]

Operation and Maintenance Impacts

n/a

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[729] Unit Energy Savings (UES) Measures and Supporting Documentation, ComFreezer_v3_0.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum

[730] 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[731].

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) * 365$$

Where:

kWhBASEdailymax [732] = *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 [733] = *See table below.*

---

[731] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 2.1, ENERGY STAR, January 2008.

[732] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[733] 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 [734]

CF = Summer Peak Coincidence Factor for measure
= 0.772 [735]

---

[734] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[735] 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 [736]

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.[737]

Operation and Maintenance Impacts

n/a

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[736] Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigerator_v3.xlsm, October 2012, Northwest Power & Conservation Council, Regional Technical Forum.

[737] 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 [738]
kBtu_req (School) = Required annual heating output of school (kBtu)
= 22,191 [739]

---

[738] 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.

[739] 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* [740]
EFbase = *Energy Factor of baseline domestic water heater*
= *0.904* [741]

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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[740] 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

[741] Ibid.

= *5885* [742]
Hours (School) = *Run hours in school*
= *2218* [743]
CF (Office) = *Summer Peak Coincidence Factor for office measure*
= *0.630* [744]
CF (School) = *Summer Peak Coincidence Factor for school measure*
= *0.580* [745]

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.[746]

Measure Life

The measure life is assumed to be 10 years.[747]

Operation and Maintenance Impacts

n/a

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[742] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.
[743] Ibid.
[744] Ibid.
[745] Ibid.
[746] 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
[747] Vermont Energy Investment Corporation "Residential Heat Pump Water Heaters: Energy Efficiency Potential and Industry Status" November 2005.

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[748] when the master load is not in use.

Annual Energy Savings Algorithm

ΔkWh = 26.9 kWh[749]

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[748] 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.

[749] Energy & Resource Solutions. 2013. Emerging Technologies Research Report; Advanced Power Strips for Office Environments prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships." Assumes savings consistent with the 20W threshold setting for the field research site (of two) demonstrating higher energy savings. ERS noted that the 20 W threshold may be unreliable due to possible inaccuracy of the threshold setting in currently available units. It is assumed that future technology improvements will reduce the significance of this issue. Further, savings from the site with higher average savings was adopted (26.9 kWh versus 4.7 kWh) acknowledging that investigations of APS savings in other jurisdictions have found significantly higher savings. For example, Northwest Power and Conservation Council, Regional Technical Forum. 2011. "Smart Power Strip Energy Savings Evaluation" found average savings of 145 kWh.

Summary Coincident Peak kW Savings Algorithm

$\Delta kW = 0 kW$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $16 for a 5-plug $26 for a 7-plug[750].

Measure Life

The measure life is assumed to be 4 years[751].

Operation and Maintenance Impacts

n/a

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[750] NYSERDA Measure Characterization for Advanced Power Strips

[751] David Rogers, Power Smart Engineering, "Smart Strip Electrical Savings and Usability," October 2008

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 CFL adjustments.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

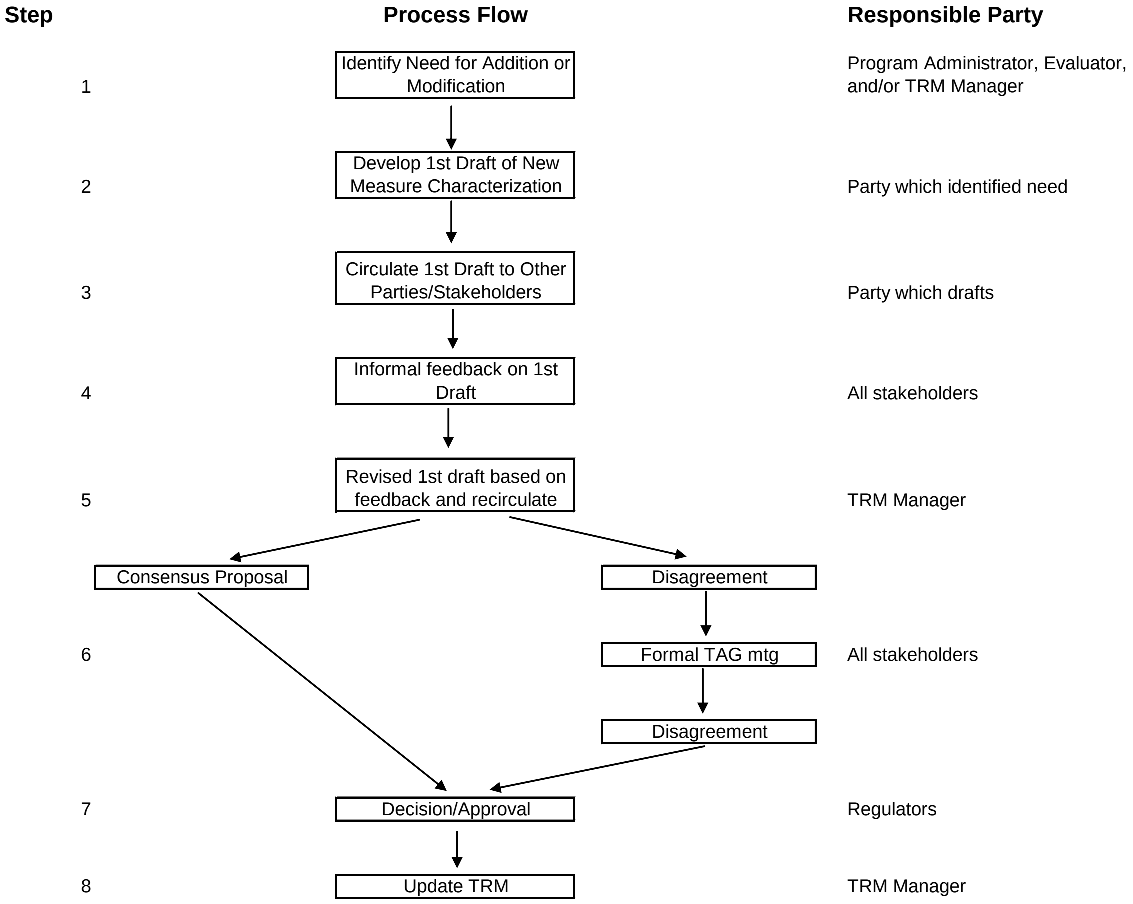
Once a TRM has been developed, it is vital that it is kept up to date, amended, and maintained in a timely and effective manner. There are three main points in time when a TRM is most likely to require changes:

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
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[752]

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[753]	Large Commercial/Industrial	3,830

Note(s): “Other” building types includes all building types except those listed above.

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[752] 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

[753] 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[754]

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[755]
Warehouse/ Industrial	Large Commercial/Industrial	0.7	0.72
	Small Commercial	0.68	0.7
Unknown[756]	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.

Waste Heat Factors for C&I Lighting – Known HVAC Types[757]

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[754] 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

[755] C&I Lighting Load Shape Project FINAL Report, KEMA, 2011

[756] 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.

[757] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March

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	1.00	0.85	0.94
	Retail	1.27	1.26	1.00	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.23	1.24	1.00	0.75	0.89
	Other	1.35	1.33	1.00	0.82	0.93
Maryland, SMECO	Office	1.36	1.32	1.10	0.85	0.94
	Retail	1.27	1.26	1.00	0.83	0.95
	School	1.44	1.44	1.00	0.81	0.96
	Warehouse	1.23	1.25	1.02	0.75	0.89
	Other	1.35	1.33	1.00	0.82	0.93
Maryland, Pepco	Office	1.36	1.32	1.00	0.85	0.94
	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.00	0.81	0.96
	Warehouse	1.23	1.25	1.00	0.75	0.89
	Other	1.35	1.33	1.08	0.82	0.93
Maryland, DPL	Office	1.35	1.32	1.00	0.85	0.94
	Retail	1.27	1.26	1.00	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.22	1.23	1.00	0.75	0.89
	Other	1.34	1.32	1.00	0.82	0.93
Maryland, Potomac Edison	Office	1.34	1.31	1.10	0.85	0.94
	Retail	1.27	1.25	1.00	0.83	0.95
	School	1.45	1.45	1.00	0.81	0.96
	Warehouse	1.2	1.21	1.02	0.75	0.89
	Other	1.33	1.31	1.00	0.82	0.93
Washington,	Office	1.36	1.32	1.00	0.85	0.94

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
D.C., All	Retail	1.27	1.26	1.06	0.83	0.95
	School	1.44	1.44	1.00	0.81	0.96
	Warehouse	1.23	1.25	1.00	0.75	0.89
	Other	1.35	1.33	1.08	0.82	0.93
Delaware, All	Office	1.35	1.32	1.00	0.85	0.94
	Retail	1.27	1.26	1.00	0.83	0.95
	School	1.44	1.44	1.10	0.81	0.96
	Warehouse	1.22	1.23	1.00	0.75	0.89
	Other	1.34	1.32	1.00	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[758]

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	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	1.25	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

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[758] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014. 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
	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
Washington, D.C., 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	1.14	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.