Northeast Energy Efficiency Partnerships

MID-ATLANTIC
TECHNICAL REFERENCE MANUAL
VERSION 2.0

A Project of the Regional Evaluation, Measurement and Verification Forum

July 2011

Prepared by Vermont Energy Investment Corporation (VEIC)

Facilitated and Managed by Northeast Energy Efficiency Partnerships

Table of Contents

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

A special thanks and acknowledgment from Elizabeth Titus on behalf of the EMV Forum staff at NEEP and project contractors at VEIC is extended to this project's subcommittee members. These individuals provided important input and guidance throughout the development of this TRM: Eugene Bradford (Southern Maryland Electric Cooperative), Daniel Cleverdon (District of Columbia Public Service Commission), Kristy Fleischmann (Baltimore Gas & Electric), Brian Gallagher (Consultant to Delaware State Energy Office), Dennis Hartline (Maryland Energy Administration), Cheryl Hindes (Baltimore Gas & Electric), Jeff King (Metropolitan Washington Council of Governments), Ruth Kiselewich (Baltimore Gas & Electric), Huilan Li (Maryland Public Service Commission), Teri Lutz (Allegheny Power), Laura Magee (PEPCO Holdings, Inc.), Ed Miller (Allegheny Power), Gary Musgrave (Allegheny Power), David Pirtle (PEPCO Holdings, Inc.), Charlie Smisson (Delaware State Energy Office), Mary Straub (Baltimore Gas & Electric), Steve Sunderhauf (PEPCO Holdings, Inc.), Lauren Swiston (Maryland Energy Administration), Sheldon Switzer (Baltimore Gas & Electric). In addition, staff from Itron, Navigant, GDS, Lockheed Martin,

and ICF have provided support to EMV Forum members of the subcommittee with this effort.

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 first generation of a document of this type 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 throughout the Mid-Atlantic region are in the early stages of implementation of efficiency programs and only just beginning to conduct significant new market research and evaluation studies. As a result, there were less local data upon which to rely than is the case in some other regions of the country. It will be important to update the TRM as efficiency programs mature and more evaluation data becomes available. 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 baseline consumption, annual energy savings, coincident peak demand savings, useful life, and incremental cost. Many of those components have a number of sub-components. 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 (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 was restricted to thirty 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 were 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. The final list of measures included those likely to provide a significant contribution to the portfolios of sponsors’ efficiency programs, plus some, such as heat pump water heaters, that are expected to increase in importance. Note that some of the thirty measures chosen were variations on other measures (e.g. two different efficiency tiers for room air conditioners). Because gas measures were not common to all sponsors, these were eliminated from the list of priority measures, but there is consensus that gas measures should be included in a future update. However 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 proceeded in two stages. The first stage was 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 was based on a comparative study of many secondary sources including existing TRMs for New Jersey, New York, Connecticut, Massachusetts and Vermont as well, as mentioned earlier, as some information that was developed for the EMV Forum Product “A2” (Common Methods Project).

The comparative analysis itself was 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 required calibration to common underlying assumptions. Wherever possible, such underlying assumptions – particularly for region-specific issues such as climate, codes and key baseline issues – were derived from the mid-Atlantic region. In the end, the comparative analysis documented the range of assumptions used in other jurisdictions for each key measure parameter, the average value for those jurisdictions and the reasons for the differences.

The second stage was 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 identified 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 were 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. This included New Jersey, Ontario, Vermont, and Ohio.

- 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, both for planning 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.

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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.

- Additional information about the program design is sometimes included in the measure description because program design can affect savings and other parameters.
- Savings algorithms are typically provided for each measure. For a number of measures, prescriptive values for each of the variables in the algorithm are provided along with the output from the algorithm. That output is the deemed assumption. For other measures, prescriptive values are provided for only some of the variables in the algorithm, with the term "actual" or "actual installed" provided for the others. In those cases – which one might call "deemed calculations" rather than "deemed assumptions" – users of the TRM are expected to use actual efficiency program data (e.g. capacities or rated efficiencies of central air conditioners) in the formula to compute savings. Note that the TRM typically provides *example calculations* for measures requiring "actual" values. These are for illustrative purposes only.
- All estimates of savings are annual savings and are assumed to be realized for each year of the measure life (unless otherwise noted).
- Unless otherwise noted, measure life is defined to be "The life of an energy consuming measure, including its equipment life and measure persistence (not savings persistence)" (EMV Forum Glossary). Conceptually it is similar to expected useful life, but the results are not necessarily derived from modeling studies, and many are from a report completed for New England program administrators' and regulators' State Program Working Group that is currently used to support the New England Forward Capacity Market M&V plans.
- Where deemed values for savings are provided, these represent average savings that could be expected from the average measures that might be installed in the region in 2011.
- 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 <u>*all*</u> summer weekdays (regardless of temperature). The second way is presented so that values can be bid into the PJM RPM.
- Wherever possible, savings estimates and other assumptions are based on mid-Atlantic data. For example, data from a BG&E metering study of residential central air conditioners was used to estimate both full load hours and system peak coincidence factors. However, a number of assumptions – including assumptions regarding peak coincidence factors – are based on New York and/or New England sources. While this information is not perfectly transferable, due to differences in definitions of peak periods as well as

geography and climate and customer mix, it was used because it was the most transferable and usable source available at the time.[3]

- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and transparently, and they are widely accepted in the industry. Unlike simulation model results, they also provide flexibility and opportunity for users to substitute locally specific information and to update some or all parameters as they become available on an ad hoc basis. One limitation is that certain interaction effects between end uses, such as how reductions in waste heat from many efficiency measures impacts space conditioning, are not universally captured in this version of the TRM.[4]
- For some of the whole-building program designs that are being planned or implemented in the Mid-Atlantic, simulation modeling may be needed to estimate savings. While they were beyond the scope of this TRM, it is recommended that a future version of the TRM may include the baseline specifications for any whole-building efficiency measures.
- In general, the baselines included in the TRM are intended to represent average conditions in the Mid-Atlantic. Some are based on data from the Mid-Atlantic, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Mid-Atlantic data are not available.
- When weather adjustments were needed in extrapolations, Baltimore weather conditions were generally used as a proxy for the region. This decision was made after comparing Baltimore, MD, Washington, D.C., Dover, DE and other temperature and humidity indicators.
- The TRM anticipates the effects of changes in efficiency standards for some measures, specifically CFLs and motors.

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. Future TRM updates may also expand the parameters, measures or programs covered beyond those currently included.

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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.

[4] They are captured only for lighting measures.

TRM Update History

Version	Issued
1.1	October 2010
1.2	March 2011
2.0	July 2011

RESIDENTIAL MARKET SECTOR

Lighting End Use

CFL Screw base, Retail - Residential

Unique Measure Code(s): RS_LT_TOS_CFLSCR_V1.0510

Effective Date: March 2011
End Date: December 31, 2011

Measure Description

A compact fluorescent light bulb (CFL) is purchased in retail and installed in a residential location. The incremental cost of the CFL compared to an incandescent light bulb is offset via either rebate coupons or via upstream markdowns. Assumptions are based on a time of sale purchase, not as a retrofit or direct install installation. Also, this characterization is for a general purpose screw based CFL bulb, and not a specialty bulb.

Definition of Baseline Condition

The baseline is the purchase and installation of a standard incandescent light bulb.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

$$\Delta kWh = ((\Delta Watts) / 1000) * ISR * HOURS * WHFe$$

Where:

*$\Delta Watts$ = Compact Fluorescent Watts (if known) * 2.95* [5]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from

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[5] 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.

the Energy Independence and Security Act of 2007 discussed below:

CFL Wattage	**Delta Watts Multiplier**[6]			
	2009 - 2011	**2012**	**2013**	**2014 and Beyond**
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use 45.7 [7]

Note: The delta watts should be adjusted to 28.2[8] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

ISR = *In Service Rate or percentage of units rebated that get installed.*
= *0.88* [9]

HOURS = *Average hours of use per year*
= *1088 (2.98 hrs per day)* [10]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.14* [11]

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[6] 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.

[7] RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

[8] Calculated by multiplying 45.7 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.

[9] Starting with a first year ISR of 0.81 (based on EmPOWER Maryland DRAFT 2010 Interim 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 16% 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 0.81 + (0.43*0.16) = 0.88. See MidAtlantic CFL Adjustments.xls for calculation.

[10] Based on EmPOWER Maryland DRAFT 2010 Interim Evaluation Report; Chapter 5: Lighting and Appliances.

[11] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE

For example:

$$\Delta kWh = ((45.7)/1000) * 0.88 * 1088 * 1.14$$

$$= 49.9 \text{ kWh}$$

Baseline Adjustment[12]

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[13]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Lighting waste heat cooling factor for Washington DC (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc). Assuming 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[12] Note that the EISA adjustments discussed only apply to general purpose CFL bulbs. Specialty bulbs (not characterized here) are not currently subject to these adjustments.

[13] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

Summer Coincident Peak kW Savings Algorithm

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

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.39* [14]

CF = *Summer Peak Coincidence Factor for measure*
= *0.11* [15]

For example:

$$\Delta kW = ((45.7) / 1000) * 0.88 * 1.39 * 0.11$$

$$= 0.0061 \text{ kW}$$

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

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 \$3.[16]

Measure Life

The measure life is assumed to be 5.7 years.[17]

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[14] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.39 (calculated as 1 + (0.78 / 2.0)). Based on 2.0 COP cooling system efficiency during peak hours, and 78% of homes having central cooling (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[15] RESIDENTIAL LIGHTING MARKDOWN IMPACT EVALUATION, FINAL, January 20, 2009, Submitted to: Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont. Submitted by: Nexus Market Research, Inc., RLW Analytics, Inc.

[16] Based on review of TRM assumptions for other States.

[17] 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

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	$2.00
Component Life (years) (based on lamp life / assumed annual run hours)	1[18]	3[19]

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

CFL wattage	NPV of baseline Replacement Costs[20]				
	2010	2011	2012	2013	2014 on
21W+	$4.59	$4.37	$2.98	$2.98	$2.98
16-20W	$3.65	$4.59	$4.37	$2.98	$2.98
15W and less	$3.90	$3.65	$3.39	$3.12	$2.98

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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 16% 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 * 0.16)/0.88) *5.2) = 5.7 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.[17]

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

[19] VEIC best estimate of future technology.

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

Hardwired CFL Fixtures (Interior)

Unique Measure Code(s): RS_LT_RTR_CFLFIN_V1.0510 and RS_LT_INS_CFLIN_V1.0510

Effective Date: March 2011
End Date:

Measure Description

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either retrofit or new installation.

Definition of Baseline Condition

The baseline condition is a standard incandescent interior fixture.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

$$\Delta kWh = ((\Delta Watts) /1000) * ISR * HOURS * WHFe$$

Where:

ΔWatts = *Compact Fluorescent Watts (if known) * 2.95* [21]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below:

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[21] This is the same ratio as the CFL bulb, and is used for fixtures in the absence of better data since the Nexus Market Research study only provided delta watts and did not specify incandescent or CFL fixture wattages. 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.

CFL Wattage	**Delta Watts Multiplier**[22]			
	2009 - 2011	**2012**	**2013**	**2014 and Beyond**
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use = 48.7 [23]

Note: The delta watts should be adjusted to 30.1[24] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

ISR = *In Service Rate or percentage of units rebated that get installed. =0.95* [25]

HOURS = *Average hours of use per year*
= *1088 (2.98 hrs per day)* [26]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.14* [27]

For example:

ΔkWh = ((48.7) / 1000) * 0.95 * 1088 * 1.14

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[22] 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 for calculation.

[23] Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004, p. 43 (Table 4-9). This value for delta watts is per fixture, not per lamp.

[24] 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.

[25] 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).

[26] Based on EmPOWER Maryland DRAFT 2010 Interim Evaluation Report; Chapter 5: Lighting and Appliances. This study is based on both lamp and fixture lighting logger results.

[27] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC. (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc). Assuming 7834% of homes have central cooling (based on BGE 2005 Residential Appliance Saturation Survey (RASS)).

= 57 kWh

Baseline Adjustment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[28]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Summer Coincident Peak kW Savings Algorithm

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

Where:

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[28] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.39* [29]
CF = *Summer Peak Coincidence Factor for measure*
= *0.11* [30]

For example:

ΔkW = (48.7 / 1000) * 0.95 * 1.39 * 0.11

= 0.007 kW

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for an interior fixture is assumed to be $15.[31]

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[32] 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.

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[29] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.39 (calculated as 1 + (0.78 / 2.0)). Based on 2.0 COP cooling system efficiency during peak hours, and 78% of homes having central cooling (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[30] RESIDENTIAL LIGHTING MARKDOWN IMPACT EVALUATION, FINAL, January 20, 2009, Submitted to: Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont. Submitted by: Nexus Market Research, Inc., RLW Analytics, Inc.

[31] Estimate based on review of TRM assumptions from other States.

[32] 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.

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	$2.00	$3.50
Component Life (years) (based on lamp life / assumed annual run hours)	1[33]	3[34]	8

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

CFL wattage	NPV of baseline Replacement Costs[35]				
	2010	2011	2012	2013	2014 on
21W+	$2.70	$2.47	$3.21	$3.21	$3.21
16-20W	$1.69	$2.70	$4.72	$3.21	$3.21
15W and less	$1.96	$1.69	$3.66	$3.37	$3.21

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

[34] VEIC best estimate of future technology.

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

Hardwired CFL Fixtures (Exterior)

Unique Measure Code(s): RS_LT_RTR_CFLFEX_V1.0510 and RS_LT_INS_CFLFEX_V1.0510
Effective Date: May 2010
End Date:

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.

Definition of Baseline Condition

The baseline condition is a standard incandescent exterior fixture.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

$$\Delta kWh = ((\Delta Watts) / 1000) * ISR * HOURS$$

Where:

ΔWatts = *Compact Fluorescent Watts (if known) * 2.95* [36]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below:

---

[36] This is the same ratio as the CFL bulb, and is used for fixtures in the absence of better data since the Nexus Market Research study only provided delta watts and did not specify incandescent or CFL fixture wattages. 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.

CFL Wattage	Delta Watts Multiplier[37]			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use 94.7 [38]

Note: The delta watts should be adjusted to 58.5[39] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

ISR = *In Service Rate or percentage of units rebated that get installed*
= *0.87* [40]

HOURS = *Average hours of use per year*
= *1643 (4.5 hrs per day)*[41]

For example:

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

$$= 135 \text{ kWh}$$

Baseline Adjustment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and

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[37] 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 for calculation.

[38] Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 43 (Table 4-9). This value for delta watts is per fixture, not per lamp.

[39] 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.

[40] 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).

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

100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[42]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((\Delta Watts) / 1000) * ISR * CF$$

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0.018* [43]

For example:

$$\Delta kW = (94.7 / 1000) * 0.87 * 0.018$$

---

[42] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

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

= 0.0015 kW

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

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 $20.[44]

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[45] 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:

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[44] Estimate based on review of TRM assumptions from other States.

[45] 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.

	Baseline		Efficient
	Standard Incandescent	Efficient Incandescent	CFL
Replacement Cost	$0.50	$2.00	$3.50
Component Life (years) (based on lamp life / assumed annual run hours)	0.5[46]	2.0[47]	5[48]

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

CFL wattage	**NPV of baseline Replacement Costs[49]**				
	2010	**2011**	**2012**	**2013**	**2014 on**
21W+	$4.36	$3.81	$1.92	$1.92	$1.92
16-20W	$3.77	$4.36	$3.81	$1.92	$1.92
15W and less	$4.33	$3.77	$3.19	$2.57	$1.92

---

[46] Assumes rated life of incandescent bulb of 1000 hours (simplified to 0.5 for calculation).
[47] VEIC best estimate of future technology.
[48] Assumes rated life of 8000 hours (simplified to 5 years for calculation).
[49] Note, these values have been adjusted by the appropriate In Service Rate.

Solid State Lighting (LED) Recessed Downlight Lamp

Unique Measure Code: RS_LT_TOS_SSLDWN_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight lamp 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[50]. The characterization of this measure should not be applied to other types of LEDs.

Note, this measure assumes the baseline is a Bulged Reflector (BR) lamp. This lamp type is generally the cheapest and holds by far the largest market share for this fixture type. They currently are *not* subject to EISA regulations and so this characterization does not include the baseline shift provided in other lighting measures.

Definition of Baseline Condition

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

$$\Delta kWh = ((BaseWatts - EffWatts) / 1{,}000) * ISR * HOURS * WHFe$$

Where:

BaseWatts = *Connected load of baseline lamp*

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

= 65W [51]
EffWatts = Connected load of efficient lamp
= 12W [52]
ISR = In Service Rate or percentage of units rebated that get installed.
= 0.95 [53]
HOURS = Average hours of use per year
= 1241 (3.4 hrs per day)[54]
WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.
= 1.14 [55]

$$\Delta kWh = ((65-12) / 1{,}000) * 0.95 * 1241 * 1.14$$

$$= 71 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((BaseWatts - EffWatts) / 1000) * ISR * WHFd * CF$$

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting
= 1.39 [56]

---

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

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

[53] VEIC estimate. Assumed higher than CFL because significantly higher cost.

[54] There is an absence of evaluations that have looked at SSL lamp run hours so the estimate provided is based on professional judgment. The assumption is that the installation of a more expensive LED downlight will be in a high use location. Therefore assume CFL run hour finding from 12 years ago, when the same was true of CFLs; 3.4 hours based on Xenergy 1998 study "Process and Impact Evaluation of Joint Utilities Starlights Residential Lighting Program".

[55] Waste heat factor for energy to account for cooling savings from efficient lighting. The value is estimated at 1.14 (calculated as 1 + (0.78*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC (http://lighting.bki.com/pubs/b6_tab1.htm) and assuming typical cooling system operating efficiency of 2.5 COP (accounting for distribution losses, inadequate airflow etc). Assuming 78% of homes have central cooling (based on BGE Residential Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[56] Waste heat factor for demand to account for cooling savings from efficient lighting. The value is estimated at 1.39 (calculated as 1 + (0.78 / 2.0)). Based on 2.0 COP cooling system

CF = *Summer Peak Coincidence Factor for measure*
= *0.11* [57]

ΔkW = ((65 – 12) / 1,000) * 0.95 * 1.39 * 0.11

= 0.0077 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 $61[58].

Measure Life

The measure life is assumed to be 20 yrs[59].

Operation and Maintenance Impacts

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

	BR-type Incandescent
Replacement Cost	$4.00
Component Life (years) (based on lamp life / assumed annual run hours)	1.6[60]

The calculated net present value of the baseline replacement costs is $30.85.

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efficiency during peak hours, and 78% of homes having central cooling (based on BGE Energy Use Survey, Report of Findings, December 2005; Mathew Greenwald & Associates).

[57] RESIDENTIAL LIGHTING MARKDOWN IMPACT EVALUATION, FINAL, January 20, 2009, Submitted to: Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont. Submitted by: Nexus Market Research, Inc., RLW Analytics, Inc.

[58] 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.

[59] 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 therefore assumed to be 20 yrs (25000/1241); http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/SSL_FinalCriteria.pdf

[60] Assumes rated life of BR incandescent bulb of 2000 hours, based on product review. Lamp life is therefore 2000/1241 = 1.6years.

Refrigeration End Use

Refrigerator

Unique Measure Code(s): RS_RF_TOS_REFRIG_V10.05
Effective Date: March 2011
End Date:

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). This is a time of sale measure characterization.

Definition of Baseline Condition

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

Definition of Efficient Condition

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

Annual Energy Savings Algorithm[61]

$$\Delta kWh = kWhBASE - kWhES$$

Where:

kWhBASE = *Annual energy consumption of baseline unit*
= *585.4*
kWhES = *Annual energy consumption of ENERGY STAR unit*
= *468.3*
Or = *Annual energy consumption of CEE Tier 2 unit*
= *439.1*

---

[61] kWh assumptions for base and efficient condition are based on data compiled by Efficiency Vermont that gives the average federal standard consumption for all units incentivized in their program. ENERGY STAR standards are 20% better than Federal Standard; CEE Tier 2 is 25% better.

$\Delta kWH_{ENERGY\ STAR}$

$= 585.4 – 468.3$

$= 117$ kWh

$\Delta kWH_{CEE\ TIER\ 2}$

$= 585.4 – 439.1$

$= 146$ kWh

Summer Coincident Peak kW Savings Algorithm

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

Where:

TAF = Temperature Adjustment Factor

= 1.23 [62]

LSAF = Load Shape Adjustment Factor

= 1.15 [63]

$\Delta kW_{ENERGY\ STAR}$

$= (117 / 8760) * 1.23 * 1.15$

$= 0.019$ kW

$\Delta kW_{CEE\ TIER\ 2}$

$= (146 / 8760) * 1.23 * 1.15$

$= 0.024$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[62] 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.

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

The incremental cost for this measure is assumed to be $95 for an ENERGY STAR unit and $140 for a CEE Tier 2 unit.[64]

Measure Life

The measure life is assumed to be 17 Years.[65]

Operation and Maintenance Impacts

n/a

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

[65] Consistent with Efficiency Vermont and New Jersey TRMs.

Refrigerator Early Retirement

Unique Measure Code(s): RS_RF_ERT_REFRIG_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure involves the removal of an existing inefficient refrigerator[66] 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[67].

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

$$\Delta kWh = UECretired * ISAF$$[68]

---

[66] 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.

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

[68] There is currently no net to gross (NTG) ratio applied in this algorithm.
A NTG ratio was originally used to account for i) primary units being recycled (as opposed to secondary), ii) refrigerators only used part of the year and iii) for those that would have been removed without the program (i.e. freeriders). The new methodology addresses the first (i) and second (ii) issues because the algorithm incorporates replacement and partial-use adjustments. No other measures in the TRM include free-rider estimates at this time. The freerider adjustment has been removed to make this measure more consistent with the other measures in this TRM.

Where:

UECretired = Average in situ Unit Energy Consumption of retired unit, adjusted for part use
= 894 kWh[69]

ISAF = In Situ Adjustment Factor
= 0.85[70]

ΔkWh = 894 * 0.85

= 760 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (ΔkWh/8760) * TAF * LSAF

Where:

TAF = Temperature Adjustment Factor
= 1.23 [71]

LSAF = Load Shape Adjustment Factor
= 1.066 [72]

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[69] Based on EmPower DRAFT 2010 Interim Evaluation Report Chapter 5: Lighting and Appliances. This suggests an average UEC of 1004kWh and an average part use factor of 0.89 to give an adjusted value of 894kWh.

[70] A recent California study suggests that in situ energy consumption of refrigerators is lower than the DOE test procedure would suggest (The Cadmus Group et al., “Residential Retrofit High Impact Measure Evaluation Report”, prepared for the California Public Utilities Commission, February 8, 2010). The magnitude of the difference – estimated as 6% lower for one California utility, 11% lower for a second, and 16% lower for a third – was a function of whether the recycled appliance was a primary or secondary unit, the size of the household and climate (warmer climates show a small difference between DOE test procedure estimated consumption and actual consumption; cooler climates had lower in situ consumption levels). Ideally, such an adjustment for the Mid Atlantic should be computed using program participant data. However, in the absence of such a calculation, a 15% downward adjustment, which is near the high end of the range found in California, is assumed to be reasonable for Mid Atlantic given its cooler climate (relative to California).

[71] 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.

[72] 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.

$$\Delta kW = 760/8760 * 1.23 * 1.066$$

$$= 0.114 \text{ kW}$$

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.[73]

Operation and Maintenance Impacts

n/a

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[73] 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_V1.0510 and RS_HV_TOS_FANMTR_V1.0510
Effective Date: March 2011
End Date:

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 [74]

Cooling Season kWh Savings from efficient fan motor = 178kWh [75]

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[74] 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).

[75] The average cooling savings from Scott Pigg (Energy Center of Wisconsin), "Electricity Use by New Furnaces: A Wisconsin Field Study", Technical Report 230-1, October 2003, is 70 to 95kWh. An estimate for Mid-Atlantic is provided by multiplying by the ratio of full load cooling hours in Baltimore compared to Southern Wisconsin (1050/487). Full load hour estimates from:

Summer Coincident Peak kW Savings Algorithm

Two methodologies are provided below, the first is a deemed value to use if the appropriate sizing data is not collected, the second provides an algorithm based on the size of the cooling unit.

1. Deemed Summer Coincident Peak kW Assumption

$$\Delta kWcooling = \Delta kW * CF$$

Where:

ΔkW = *Difference in connected load kW of baseline motor and efficient fan motor*
= *0.163* [76]

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [77]

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* [78]

$$\Delta kWcooling_{SSP} = 0.163 * 0.69$$

$$= 0.112 \text{ kW}$$

$$\Delta kWcooling_{PJM} = 0.163 * 0.66$$

$$= 0.108 \text{ kW}$$

2. Summer Coincident Peak kW based on cooling system size

$$\Delta kWcooling = \Delta kW * CF$$

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

[76] The average delta watts power draw for a furnace with ECM compared to without is 162.5W, from Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003, p34.

[77] 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.

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

Where:

ΔkW = *Difference in connected load kW of baseline motor and efficient fan motor*[79]
= $(-0.023 * Tons^2) + (0.062 * Tons) + 165$

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [80]

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* [81]

For example, a four ton cooling unit:

$\Delta kWcooling_{SSP}$ = $((-0.023 * 4^2) + (0.062 * 4) + 0.165) * 0.69$
= 0.031 kW

$\Delta kWcooling_{PJM}$ = $((-0.023 * 4^2) + (0.062 * 4) + 0.165) * 0.66$
= 0.030 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 $200.[82]

Measure Life

The measure life is assumed to be 18 years.[82]

Operation and Maintenance Impacts

n/a

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[79] The polynomial algorithm is based on data pulled from the chart on p34 of Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003.

[80] 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.

[81] 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.

[82] 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_V1.0510 and RS_HV_TOS_RA/CT1_V1.0510
Effective Date: March 2011
End Date:

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 1 minimum qualifying efficiency specifications presented below:

Product Class (Btu/hour)	Federal Standard (EER)	ENERGY STAR (EER)	CEE TIER 1 (EER)
8,000 to 13,999	>= 9.8	>= 10.8	>= 11.3

Definition of Baseline Condition

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

Definition of Efficient Condition

The baseline condition is a window AC unit that meets either the ENERGY STAR of CEE TIER 1 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[83]
Btu/hour = Size of rebated unit

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[83] 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.

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 [84]
EERbase = Efficiency of baseline unit in Btus per Watt-hour
= 9.8 [85]
EERee = Efficiency of ENERGY STAR unit in Btus per Watt-hour
= 10.8 [86]
Or = Efficiency of CEE Tier 1 unit
= 11.3 [87]

$\Delta kWH_{ENERGY\ STAR}$
= (325 * 8500 * (1/9.8 – 1/10.8)) / 1000
= 26 kWh
$\Delta kWH_{CEE\ TIER\ 1}$
= (325 * 8500 * (1/9.8 – 1/11.3)) / 1000
= 37 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)*
= 0.56 [88]
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[89]

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

[85] Minimum Federal Standard for capacity range.

[86] Minimum qualifying for ENERGY STAR, or CEE Tier 1.

[87] Minimum qualifying for ENERGY STAR, or CEE Tier 1.

[88] 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) and adjusted for the region based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps."

$\Delta kW_{ENERGY\ STAR\ SSP}$
$= (8500 * (1/9.8 – 1/10.8)) / 1000 * 0.56$
$= 0.045$ kW
$\Delta kW_{CEE\ TIER\ 1\ SSP}$
$= (8500 * (1/9.8 – 1/11.3)) / 1000 * 0.56$
$= 0.065$ kW

$\Delta kW_{ENERGY\ STAR\ PJM}$
$= (8500 * (1/9.8 – 1/10.8)) / 1000 * 0.30$
$= 0.024$ kW
$\Delta kW_{CEE\ TIER\ 1\ PJM}$
$= (8500 * (1/9.8 – 1/11.3)) / 1000 * 0.30$
$= 0.035$ 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 $40 for an ENERGY STAR unit and $80 for a CEE TIER 1 unit.[90]

Measure Life

The measure life is assumed to be 12 years.[91]

Operation and Maintenance Impacts

n/a

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

[91] 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_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a new Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This measure could relate to the replacing of an existing unit or the installation of a new system in an existing home (time of sale).

Efficiency Level	**SEER Rating**	**EER Rating**[92]
Federal Standard	13	11
ENERGY STAR	14.5	12

Definition of Baseline Condition

The baseline condition is a central air conditioning ducted split system that meets the minimum Federal standards.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

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

Where:

Hours = Full load cooling hours

Dependent on location as below:

Location	*Run Hours*
Wilmington, DE	*513* [93]

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[92] SEER and EER refer to Seasonal Energy Efficiency Ratio and Energy Efficiency Ratio, respectively.

[93] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 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	*531* [94]
Washington, DC	*668* [93]

Btu/Hour = *Size of equipment in Btu/hour (note 1 ton = 12,000Btu/hour)*
= *Actual installed*
SEERbase = *SEER Efficiency of baseline unit*
= *13* [95]
SEERee = *SEER Efficiency of ENERGY STAR unit*
= *Actual installed*

For example, a 3 ton unit with SEER rating of 14.5, in Baltimore:

$$\Delta kWH = (531 * 36000 * (1/13 - 1/14.5)) / 1000$$

$$= 152 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:
EERbase = *EER Efficiency of baseline unit*
= *11* [96]
EERee = *EER 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* [97]
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* [98]

Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

[94] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[95] Minimum Federal Standard.

[96] Minimum Federal Standard.

[97] 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.

For example, a 3 ton unit with EER rating of 12:

$$\Delta kW_{SSP} = (36000 * (1/11 - 1/12)) / 1000 * 0.69$$

$$= 0.19 \text{ kW}$$

$$\Delta kW_{PJM} = (36000 * (1/11 - 1/12)) / 1000 * 0.66$$

$$= 0.18 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below:[99]

Efficiency Level	Cost per Ton
SEER 14	$119
SEER 15	$238
SEER 16	$357
SEER 17	$476
SEER 18	$596
SEER 19	$715
SEER 20	$834
SEER 21	$908

Measure Life

The measure life is assumed to be 18 years.[100]

Operation and Maintenance Impacts

n/a

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[98] 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.

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

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

Duct Sealing

Unique Measure Code: RS_HV_RTR_DCTSLG_V2.0711
Effective Date: July 2011
End Date:

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:

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

Where:

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

$CFM50_{\text{Envelope Only}}$ = *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 $CFM25_{DL}$[101] 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* [102]

Default = 0.5[103]

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[101] 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).

[102] 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*[104]
Default = 0.25[105]

c. Calculate Energy Savings:

$\Delta kWh_{cooling}$ = $((\Delta CFM25_{DL}) / (Capacity * 400)) * FLHcool * BtuH) / 1000 / \eta Cool$

Where:

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

Location	*FLHcool*
Wilmington, DE	*513* [106]
Baltimore, MD	*531* [107]
Washington, DC	*668*

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*[108]*:*

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

[104] 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

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

[106] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 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)

107 Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[108] 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*

For example, duct sealing in a house in Wilmington, DE with 3 ton, SEER 11 central air conditioning and the following blower door test results:

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

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

Duct Leakage at CFM50:

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

$CFM50_{\text{DL after}}$ = (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:
ΔkWh = ((119 / (3 * 400)) * 513 * 36,000) / 1,000 / 11

= 166 kWh

---

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

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

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

Where:

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

Location	**FLHheat**
Wilmington, DE	*1291*[109]
Baltimore, MD	*1195*[110]
Washington, DC	*1134*

BtuH = Size of equipment in Btuh (note 1 ton = 12,000Btuh)
= Actual
ηHeat = Efficiency in COP of Heating equipment
= actual. If not available use[111]*:*

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*

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

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[109] 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)

[110] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

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

$$\Delta kWh = (((119 / (3 * 400)) * 1{,}195 * 36{,}000) / 1{,}000{,}000 / 2.5) * 293.1$$

$$= 500 \text{ kWh}$$

Methodology 2: Evaluation of Distribution Efficiency

Cooling savings from reduction in Air Conditioning Load:

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

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

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	*513* [112]
Baltimore, MD	*531* [113]
Washington, DC	*668*

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*[114]*:*

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[112] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 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)

[113] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[114] 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.

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

For example, 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:

$$\Delta kWh = ((0.90 – 0.80)/0.90) * 513 * 36{,}000) / 1{,}000 / 11$$

$$= 187 \text{ kWh}$$

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

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

Where:

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

Location	**FLHheat**
Wilmington, DE	*1,291*[115]
Baltimore, MD	*1,195*[116]
Washington, DC	*1,134*

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

ηHeat = *Efficiency in COP of Heating equipment*
= *actual. If not available use*[117]*:*

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[115] 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)

[116] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[117] These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*
Heat Pump	*Before 2006*	*6.8*	*2.00*
	After 2006	*7.7*	*2.26*
Resistance	*n/a*	*n/a*	*1.00*

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

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

Energy Savings:

$$\Delta kWh = ((((0.90 – 0.80)/0.90) * 1{,}195 * 36{,}000) / 1{,}000{,}000 / 2.5) * 293.1$$

$$= 560 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

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

Where:

CF_{SSP} *= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= 0.69 [118]

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 [119]

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

[118] 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.

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

Annual Fossil Fuel Savings Algorithm

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)*[120]

FLHheat = *Full Load Heating Hours*

= *620*[121]

ηHeat = *Efficiency of Heating equipment*

= *Actual*[122]*. If not available use 84%*[123]*.*

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

Energy Savings:

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

$$= 7.3 \text{ MMBtu}$$

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[120] 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.

[121] 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.

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

[123] 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%.

Methodology 2: Evaluation of Distribution Efficiency

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

Where:

DE_{after} = Distribution Efficiency after duct sealing

DE_{before} = Distribution Efficiency before duct sealing

FLHheat = Full Load Heating Hours

= 620[124]

BtuH = Capacity of Heating System

= Actual

ηHeat = Efficiency of Heating equipment

= Actual[125]*. If not available use 84%*[126]*.*

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

DE_{before} = 0.80

DE_{after} = 0.90

Energy Savings:

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

= 8.6 MMBtu

Annual Water Savings Algorithm

n/a

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[124] 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.

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

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

Incremental Cost

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

Measure Life

The measure life is assumed to be 20 years[127].

Operation and Maintenance Impacts

n/a

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[127] 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_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of a new Air Source Heat Pump split system meeting ENERGY STAR efficiency standards presented below. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

Efficiency Level	**HSPF**	**SEER Rating**	**EER Rating**[128]
Federal Standard	7.7	13	11
ENERGY STAR	8.2	14.5	12

Definition of Baseline Condition

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

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

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

Where:

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

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

Location	*FLHcool*
Wilmington, DE	*513* [129]
Baltimore, MD	*531* [130]
Washington, DC	*668*

BtuH = *Capacity of Air Source Heat Pump (1 ton = 12,000Btuh)*
= *Actual*

SEERbase = *Efficiency in SEER of baseline Air Source Heat Pump*
= *13*[131]

SEERee = *Efficiency in SEER of efficient Air Source Heat Pump*
= *Actual*

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

Location	**FLHheat**
Wilmington, DE	*1,291*[132]
Baltimore, MD	*1,195*[133]
Washington, DC	*1,134*

HSPFbase = *Heating Seasonal Performance Factor of baseline Air Source Heat Pump*
= *7.7* [134]

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[129] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 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)

130 Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[131] Minimum Federal Standard

[132] 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)

[133] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[134] Minimum Federal Standard

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

For example, a 3 ton unit with a SEER rating of 14.5 and HSPF of 8.4 in Baltimore, MD:

$$\Delta kWH = (531 * 36,000 * (1/13 - 1/14.5))/1,000 + (1,195 * 36,000 * (1/7.7 - 1/8.4))/1,000$$

$$= 618 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = BtuH * (1/EERbase - 1/EERee))/1,000 * CF$$

Where:

EERbase = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*
= *11* [135]

EERee = *Energy Efficiency Ratio (EER) of Efficient Air Source Heat Pump*
= *Actual*
If EER is unknown, calculate based on SEER[136]*:*
$= (-0.02 * SEER^2) + (1.12 * SEER)$

CF_{SSP} = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [137]

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* [138]

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[135] Minimum Federal Standard

[136] Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[137] 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.

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

For example, a 3 ton unit with EER rating of 12.0 in Baltimore, MD:

ΔkW = 36,000 * (1/11 - 1/12))/1,000 * 0.69

= 0.19 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[139]. 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	$137
15	$274
16	$411
17	$548
18	$685

Measure Life

The measure life is assumed to be 18 years[140].

Operation and Maintenance Impacts

n/a

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

[140] 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

HE Gas Boiler

Unique Measure Code: RS_HV_TOS_GASBLR_V2.0711
Effective Date: July 2011
End Date:

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 of 80 %.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

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

Where:

FLHheat = Full Load Heating Hours

= 620[141]

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[141] 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*
= *0.80* [142]
AFUEee = *Efficiency in AFUE of efficient boiler*
= *Actual*

For example, the purchase and installation of a 100,000 Btuh, 90% AFUE boiler:

$$\Delta MMBtu = (620 * (100{,}000/0.8 - 100{,}000/0.9)) / 1{,}000{,}000$$

$$= 8.6 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is provided below[143]:

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

Measure Life

The measure life is assumed to be 18 years[144] .

Operation and Maintenance Impacts

n/a

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

[142] Federal baseline AFUE for boilers.

[143] 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.

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

Condensing Furnace (gas)

Unique Measure Code: RS_HV_TOS_GASFUR_V2.0711
Effective Date: July 2011
End Date:

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 %[145].

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:

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[145] The Federal baseline for furnaces is actually 78%, however experience suggests a more suitable market baseline is 80% AFUE.

FLHheat = *Full Load Heating Hours*
= *620*[146]
BtuH = *Capacity of Furnace*
= *Actual*
AFUEbase = *Efficiency in AFUE of baseline Furnace*
= *0.80*
AFUEee = *Efficiency in AFUE of efficient Furnace*
= *Actual*

For example, 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[147]:

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

Measure Life

The measure life is assumed to be 18 years[148].

Operation and Maintenance Impacts

n/a

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[146] 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.

[147] 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

[148] 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_V2.0711
Effective Date: July 2011
End Date:

Measure Description

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

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

This is a retrofit measure.

Definition of Baseline Condition

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

Definition of Efficient Condition

A programmable thermostat is installed and programmed by a professional.

Annual Energy Savings Algorithm

n/a

Summer Coincident Peak kW Savings Algorithm

n/a

Annual Fossil Fuel Savings Algorithm

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

Where:

Savings % = *Estimated percent reduction in heating load due to programmable thermostat*
= *6.8%* [149]

Heat Load = *Annual Home Heating load (MMBtu)*
= *50.1* [150]

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

$$= 3.41 \text{ MMBtu}$$

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[151].

Measure Life

The measure life is assumed to be 10 years[152].

Operation and Maintenance Impacts

n/a

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[149] 2007, RLW Analytics, "Validating the Impact of Programmable Thermostats"

[150] 50.1 MMBtu heating load is estimated based on the MD Residential Baseline Database, subtracting Base load from Base + Heat.

[151] 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.

[152] 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_V2.0711
Effective Date: July 2011
End Date:

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 9.8EER).

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 10.8EER).

Annual Energy Savings Algorithm

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

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

Savings for remaining measure life (next 9 years)

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

Where:

Hours = Run hours of Window AC unit
= 325 [153]
Btuh = Capacity of replaced unit
= Actual or 8,500 if unknown [154]
EERexist = Efficiency of existing unit in Btus per Watt-hour
= 7.7 [155]
EERbase = Efficiency of baseline unit in Btus per Watt-hour
= 9.8 [156]
EERee = Efficiency of ENERGY STAR unit in Btus per Watt-hour
= Actual

For example, an 8,500 Btuh Room AC unit with an EER rating of 10.8:

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

$$\Delta kWh = (325 * 8{,}500 * (1/7.7 – 1/10.8)) / 1{,}000$$

$$= 103\ kWh$$

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (325 * 8{,}500 * (1/9.8 – 1/10.8)) / 1{,}000$$

$$= 26\ kWh$$

Summer Coincident Peak kW Savings Algorithm

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

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

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[153] 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.

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

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

[156] Minimum Federal Standard for capacity range.

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 Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [157]

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*[158]

For example, a 8500 Btuh Room AC unit with an EER rating of 10.8

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

ΔkW_{SSP} = ((8,500 * (1/7.7– 1/10.8)) / 1,000) * 0.31

= 0.098 kW

Savings for remaining measure life (next 9 years)

ΔkW_{SSP} = ((8,500 * (1/9.8– 1/10.8)) / 1,000) * 0.31

= 0.025 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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

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

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

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

Measure Life

The measure life is assumed to be 12 years[159]. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced[160].

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[161]) * 69%[162].

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

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[159] 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

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

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

[162] 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_V2.0711
Effective Date: July 2011
End Date:

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 [163]

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[163] 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* [164]
EERexist = *Efficiency of existing unit in Btus per Watt-hour*
= *Actual or 7.7 if unknown* [165]
%replaced = Percentage of units dropped off that are replaced in the home
= 76% [166]
EERnewbase = *Efficiency of new baseline unit in Btus per Watt-hour*
= 9.8[167]

For example, the turn in of an 8,500 Btuh, 7.7 EER unit:

$$\Delta kWh = ((325 * 8{,}500 * (1/7.7))/1{,}000) - (0.76 * ((325 * 8{,}500 * (1/9.8))/1{,}000)$$

$$= 145 \text{ kWh}$$

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 Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.31* [168]

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

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

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

[166] 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.

[167] Minimum Federal Standard for capacity range. Note that we assume the replacement is only at federal standard efficiency for the reason explained above.

[168] 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 Central A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.3*[169]

For example, the turn in of an 8500 Btuh, 7.7 EER unit:

ΔkW_{SSM} = ((8,500 * (1/7.7))/1,000) -
(0.76 * ((8,500 * (1/9.8))/1,000) * 0.31

= 0.9 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[170].

Measure Life

The measure life is assumed to be 3 years[171].

Operation and Maintenance Impacts

The net present value of the deferred replacement cost (the cost associated with the replacement of those units that would be replaced, with a standard unit that would have had to have occurred in 3 years, had the existing unit not been replaced) is calculated as $89.36[172].

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[169] 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).

[170] $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.

[171] 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

[172] 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

Domestic Hot Water (DHW) End Use

Low Flow Shower Head

Unique Measure Code(s): RS_WT_INS_SHWRHD_V1.0510 and RS_WT_TOS_SHWRHD_V1.0510

Effective Date: March 2011
End Date:

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.

Definition of Efficient Condition

The efficient condition is an energy efficient showerhead using 2.0 GPM.

Annual Energy Savings Algorithm

If electric domestic water heater:

ΔkWH[173] = ((((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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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)

[173] 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 [174]

GPMlow = Gallons Per Minute of low flow showerhead
= 2.0 [175]

 # people = Average number of people per household
= 2.56 [176]

gals/day = Average gallons per day used for showering
= 11.6 [177]

days/y = Days shower used per year
= 365

Showers/home = Average number of showers in the home
= 1.6 [178]

8.3 = Constant to convert gallons to lbs

TEMPsh = Assumed temperature of water used for shower
= 105 [175]

TEMPin = Assumed temperature of water entering house
= 55 [179]

DHW Recovery Efficiency = Recovery efficiency of electric water heater
= 0.98 [180]

0.003412 = Constant to convert MMBtu to kWh

$$\Delta kWH = ((((2.5 - 2.0) / 2.5) * 2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-55) / 1{,}000{,}000) / 0.98 / 0.003412$$

---

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

[175] Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year.

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

[177] 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)

[178] 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

[179] A good approximation of annual average water main temperature is the average annual ambient air temperature. 55 degrees used based on: http://lwf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg

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

= 168 kWh

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* [181]

$\Delta kW = 168 / 45 * 0.00371$

= 0.0138 kW

Annual Fossil Fuel Savings Algorithm

If fossil fuel domestic water heater:

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* [182]

All other variables *As above*

ΔMMBtu = ((((2.5 – 2.0) / 2.5) * 2.56 * 11.6 * 365) / 1.6 * 8.3 * (105-55) / 1,000,000) / 0.75

---

[181] 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

[182] 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%.

= 0.7497 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*

Water Savings = ((((2.5 – 2.0) / 2.5) * 2.56 * 11.6 * 365)) / 1.6 / 748

= 1.81 CCF

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.[183]

Measure Life

The measure life is assumed to be 10 years.[184]

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

[184] 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_V1.0510 and RS_WT_TOS_FAUCET_V1.0510

Effective Date: May 2010

End Date:

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.

Definition of Efficient Condition

The efficient condition is an energy efficient faucet aerator using 1.5 GPM.

Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta kWH^{185} = (((((GPMbase - GPMlow) / GPMbase) * \# people * gals/day * days/year * DR) / (F/home)) * 8.3 * (TEMPft - TEMPin) / 1{,}000{,}000) / DHW Recovery Efficiency / 0.003412$$

Where:

GPMbase = Gallons Per Minute of baseline faucet
= 2.2 [186]

GPMlow = Gallons Per Minute of low flow faucet
= 1.5 [187]

---

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

[186] 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.

[187] Connecticut Energy Efficiency Fund; CL&P and UI Program Savings Documentation for 2008 Program Year.

 # people = *Average number of people per household*
= 2.56 [188]
gals/day = *Average gallons per day used by faucet*
= 10.9 [189]
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% [190]
F/home = *Average number of faucets in the home*
= 3.5 [191]
8.3 = *Constant to convert gallons to lbs*
TEMPft = *Assumed temperature of water used by faucet*
= 80 [187]
TEMPin = *Assumed temperature of water entering house*
= 55 [192]
DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= 0.98 [193]
0.003412 = *Constant to converts MMBtu to kWh*

$$\Delta kWH = ((((2.2 - 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80-55) / 1,000,000) / 0.98 / 0.003412$$

$$= 29 \text{ kWh}$$

---

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

[189] 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)

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

[191] 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

[192] A good approximation of annual average water main temperature is the average annual ambient air temperature. 55 degrees used based on: http://lwf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg

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

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* [194]

ΔkW = 29 / 22 * 0.00262

= 0.0034 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:

Gas DHW Recovery Efficiency = *Recovery efficiency of electric water heater*
= *0.75* [195]

All other variables *As above*

ΔMMBtu = ((((2.2 – 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 * 8.3 * (80-55) / 1,000,000) / 0.75

= 0.128 MMBtu

---

[194] 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

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

Annual Water Savings Algorithm

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*

Water Savings = (((2.2 – 1.5) / 2.2) * 2.56 * 10.9 * 365 * 0.5) / 3.5 / 748

= 0.619 CCF

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.[196]

Measure Life

The measure life is assumed to be 5 years.[197]

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

[197] Conservative estimate based on review of TRM assumptions from other States.

Domestic Hot Water Tank Wrap

Unique Measure Code(s): RS_WT_INS_HWWRAP_V1.0510
Effective Date: May 2010
End Date:

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

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

Where:

KWHbase = *Average KWH consumption of electric domestic hot water tank = 3460* [198]

EFnew = *Assumed efficiency of electric tank with tank wrap installed*

= *0.88* [199]

---

[198] 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

[199] The Oak Ridge study predicted that wrapping a 40 gal water heater would increase Energy Factor of a 0.86 electric DHW tank by 0.02 (to 0.88);

EFbase installed = *Assumed efficiency of electric tank without tank wrap*

= *0.86* [199]

ΔkWH = 3460 * ((0.88-0.86)/0.88)

= 79 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/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).*

ΔkW = 79 / 8760

= 0.0090 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure will be the actual cost of installing the tank wrap.

Measure Life

The measure life is assumed to be 5 years.[200]

Operation and Maintenance Impacts

n/a

“Meeting the Challenge: The Prospect of Achieving 30 percent Energy Savings Through the Weatherization Assistance Program” by the Oak Ridge National Laboratory - May 2002. http://www.cee1.org/eval/db_pdf/309.pdf

[200] 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_V2.0711
Effective Date: July 2011
End Date:

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* [201]

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

---

[201] 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*[202]
8,760 = *Hours per year*
ηDHW = *DHW Recovery efficiency (ηDHW)*
= *0.98*[203]
3413 = *Conversion from Btu to kWh*

For example, 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

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

For example, 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:

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

Where:
ηDHW = *Recovery efficiency of gas hot water heater*

---

[202] Assumes 130°F water leaving the hot water tank and average temperature of basement of 65°F.
[203] Electric water heaters have recovery efficiency of 98%: http://www.ahrinet.org/ARI/util/showdoc.aspx?doc=576

= *0.75* [204]

For example, insulating 4 feet of 0.75" pipe with R-3.5 wrap:

ΔMMBtu = ((1/1.0 – 1/4.5) * (4 * 0.196) * 65 * 8,760)/ 0.75 / 1,000,000

= 0.46 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[205].

Measure Life

The measure life is assumed to be 15 years[206].

Operation and Maintenance Impacts

n/a

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[204] 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%

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

[206] 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_V2.0711
Effective Date: July 2011
End Date:

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[207].

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[208]:

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

---

[207] 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

[208] 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* [209]

EF_{Base} = *Baseline Energy Factor*
= *0.575* [210]

EF_{Eff} = *Efficient Energy Factor*
= *Actual*[211]

For example, 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

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[209] 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.

[210] 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

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

Incremental Cost

The incremental cost for this measure is provided below[212]:

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[213].

Operation and Maintenance Impacts

n/a

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[212] 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.

[213] 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_V1.0510
Effective Date: March 2011
End Date:

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* [214]
EFnew = *Energy Factor of Heat Pump water heater*
= *2.0* [215]
EFbase = *Energy Factor of standard electric water heater*
= *0.904* [216]

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[214] 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

[215] 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

KWHcooling = Cooling savings from conversion of heat in home to water heat
= 61 [217]
KWHheating[218] *= 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 [219]

Annual Fossil Fuel Savings Algorithm

ΔMMBtu = -KWHheating (electric resistance) * 0.003412 / AFUEheating[220]
= -1043 *.003412 / .80
= -4.45 MMBTU[221]

---

[216] As above

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

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

[219] 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.

[220] 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.

[221] 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.[222]

Measure Life

The measure life is assumed to be 10 years.[223]

Operation and Maintenance Impacts

n/a

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

[223] 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

Laundry End Use

Clothes Washer

Unique Measure Code(s): RS_LA_TOS_CWASHES_V1.0510 and RS_LA_TOS_CWASHT3_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding either the ENERGY STAR (note the ENERGY STAR specification was changed as of January 1st 2011) or CEE TIER 3 minimum qualifying efficiency standards presented below:

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard 2010	**>= 1.26**	**No requirement**
Federal Standard 2011	**>= 1.26**	**<= 9.5**
ENERGY STAR 2010	**>= 1.80**	**<= 7.5**
ENERGY STAR 2011	**>= 2.20**	**<= 6.0**
CEE TIER 3	**>= 2.20**	**<= 4.5**

Efficiency Level	Modified Energy Factor (MEF)	Water Factor (WF)
Federal Standard	>= 1.26	No requirement
ENERGY STAR	>= 1.80	<= 7.5
CEE TIER 3	>= 2.20	<= 4.5

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

The Water Factor 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 Federal Standard specification was changed as of January 1st 2011. Savings assumptions for both specifications are provided.

Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the ENERGY STAR or CEE TIER 3 efficiency criteria presented above. The ENERGY STAR specification was changed as of January 1st 2011. Savings assumptions for both specifications are provided.

Annual Energy Savings Algorithm

Savings are determined using Modified Energy Factor assumptions, applying the proportion of consumption used for water heating, clothes washer and clothes dryer operation and then to the mix of domestic hot water heating fuels and dryer fuels. Savings from reduced water usage are also factored in.

For the full calculation see Clothes Washer Work Sheet, but the key assumptions and their sources are provided below:

Washer Volume = 3.23 cubic feet [224]
Baseline MEF = 1.26
ENERGY STAR 2010 MEF = 1.80
ENERGY STAR 2011 MEF = 2.0
CEE TIER 3 MEF = 2.2
Number of cycles per year = 282 [225]
% consumption for water heating, CW operation, Dryer operation
= 26%, 7%, 67% [226]

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[224] Average unit size of products participating in the Efficiency Vermont Clothes Washer rebate program.

[225] Weighted average of 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf)

[226] The Clothes Washer Technical Support Document, located at: http://www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html Energy and water savings estimates are located in Chapter 4, Engineering Analysis, Table 4.1, Page 4-5

Water savings per load (ENERGY STAR 2010)
= 28.1 gallons [227]
Water savings per load (ENERGY STAR 2011)
= 11.3 gallons [228]
Water savings per load (CEE TIER 3)
= 16.2 gallons [227]

Community/Municipal Water and Wastewater pump kWh savings per gallon water saved
= 0.0039kWh per gallon of water saved[229]

Mid-Atlantic DHW fuel mix[230]:

Fuel	% of Homes
Electric	18%
Natural Gas	61%
Oil	17%
Propane	3%

Mid-Atlantic Dryer fuel mix:[231]

Fuel	% of Homes
Electric	61%
Natural Gas	39%

$\Delta kWH_{ENERGY\ STAR\ 2010}$ = 145.1 kWh

$\Delta kWH_{ENERGY\ STAR\ 2011}$ = 153.2 kWh

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http://www.eere.energy.gov/buildings/appliance_standards/residential/pdfs/chapter_4_engineering.pdf

[227] Calculated using baseline Water Factor of 16.2, derived using assumptions from the ENERGY STAR calculator. See Clothes Washer Worksheet for more information. (http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CW)

[228] Note that in 2011 a Federal Standard Water Factor is introduced (<=9.5). This is used in the calculation of savings for ENERGY STAR 2011 units and CEE Tier 3 units.

[229] Efficiency Vermont analysis of Community/Municipal Water and Wastewater pump energy consumption showed 0.0024 kWh pump energy consumption per gallon of water supplied, and 0.0015 kWh consumption per gallon for waste water treatment.

[230] 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc8waterheating/pdf/tablehc11.8.pdf)

[231] 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic: (http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc9homeappliance/pdf/tablehc11.9.pdf)

$\Delta kWH_{CEE\ TIER\ 3}$ = 180.4 kWh

Summer Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Assumed Run hours of Clothes Washer*
= *282* [232]
CF = *Summer Peak Coincidence Factor for measure*
= *0.033* [233]

$\Delta kW_{ENERGY\ STAR\ 2010}$ = 145.1 / 282 * 0.033

= 0.017 kW

$\Delta kW_{ENERGY\ STAR\ 2011}$ = 153.2 / 282 * 0.033

= 0.018 kW

$\Delta kW_{CEE\ TIER\ 3}$ = 180.4 / 282 * 0.033

= 0.021 kW

Annual Fossil Fuel Savings Algorithm

For calculation see Clothes Washer Work Sheet. Savings are based on the mix of domestic hot water heating fuels and Dryer fuels.

ENERGY STAR 2010 unit:
MMBtu Savings Natural Gas = 0.342 MMBtu
MMBtu Savings Oil = 0.041 MMBtu
MMBtu Savings Propane = 0.008 MMBtu

ENERGY STAR 2011 unit:
MMBtu Savings Natural Gas = 0.422 MMBtu
MMBtu Savings Oil = 0.051 MMBtu

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[232] Based on assumption of 1 hour average per cycle. # cycles based on weighted average of 2005 Residential Energy Consumption Survey (RECS) for Mid-Atlantic (see CW Work Sheet). http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf

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

MMBtu Savings Propane = 0.010 MMBtu

CEE TIER 3 unit:
MMBtu Savings Natural Gas = 0.487 MMBtu
MMBtu Savings Oil = 0.059 MMBtu
MMBtu Savings Propane = 0.012 MMBtu

Annual Water Savings Algorithm

For calculation see Clothes Washer Work Sheet.

ENERGY STAR 2010 unit:
Water Savings = 10.6 CCF

ENERGY STAR 2011 unit:
Water Savings = 4.3 CCF

CEE TIER 3 unit:
Water Savings = 6.1 CCF

Incremental Cost

The incremental cost for this measure is assumed to be $250 for an ENERGY STAR unit and $450 for a CEE TIER 3 unit.[234]

Measure Life

The measure life is assumed to be 14 years.[235]

Operation and Maintenance Impacts

n/a

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[234] Survey conducted by Applied Proactive Technologies (APT), Springfield, MA.
[235] Efficiency Vermont TRM.

Shell Savings End Use

Air sealing

Unique Measure Code: RS_SL_RTR_AIRSLG_V2.0711
Effective Date: July 2011
End Date:

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[236]. 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

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

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[236] 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 $CFM_{Natural}$*[237]
= *dependent on exposure level:*

Exposure	*Well Shielded*	*24*
	Normal	*20*
	Exposed	*18*

CDH = *Cooling Degree Hours*[238]
= *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*[239]
= *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*[240]*:*

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[237] 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

[238] 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)

[239] 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*[241]

For example, a well shielded home in Wilmington, DE with a 12 SEER Air Conditioning unit, has pre and post blower door test results of 3,400 and 2,250.

ΔkWh = [(((3,400 – 2,250) / 24) *60 * 7,514 * 0.75 * 0.018) / 1,000 / 12] * 6.9

= 168 kWh

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

ΔkWh = ((((CFM50Exist – CFM50New) / N-factor) * 60 * 24 * HDD * 0.018) / 1,000,000 / ηHeat) * 293.1

Where:

N-factor = *conversion from* CFM_{50} *to* $CFM_{Natural}$[242]
= *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

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[240] 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.

[241] 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.

[242] 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

HDD = *Heating Degree Days*
= *dependent on location*[243]

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*[244]*:*

System Type	*Age of Equipment*	*HSPF Estimate*	*COP Estimate*[245]
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

For example, a well shielded home in Wilmington, DE with a heat pump with COP of 2.5, has pre and post blower door test results of 3,400 and 2,250.

ΔkWh = [(((3,400 – 2,250) / 24) *60 * 24 * 3,275 * 0.018) / 1,000,000 / 2.5] * 293.1

477 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh / FLHcool * CF

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[243] 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.

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

[245] To convert HSPF to COP, divide the HSPF rating by 3.413.

Where:

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	**FLHcool**
Wilmington, DE	*513* [246]
Baltimore, MD	*531* [247]
Washington, DC	*668*

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

= *0.69* [248]

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* [249]

For example, 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.

$$\Delta kW = 168 / 513 * 0.69$$

$$= 0.23 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

For homes with Fossil Fuel Heating:

$$\Delta MMBTU = (((CFM50Exist – CFM50New) / N\text{-}factor) *60 * 24 * HDD * 0.018) / 1{,}000{,}000 / \eta Heat$$

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[246] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 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)

[247] Based on BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[248] 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.

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

Where:

N-factor = *conversion from CFM_{50} to $CFM_{Natural}$*[250]

= *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*[251]

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*[252]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[253]*.*

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[250] 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

[251] 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.

[252] 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.

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

For example, a well shielded home in Wilmington, DE with a 70% heating system efficiency, has pre and post blower door test results of 3,400 and 2,250.

$$\Delta MMBtu = (((3{,}400 - 2{,}250) / 24) * 60 * 24 * 3{,}275 * 0.018) / 1{,}000{,}000 / 0.7$$

$$= 5.8 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure should be the actual installation and labor cost to perform the air sealing work.

Measure Life

The measure life is assumed to be 15 yrs[254].

Operation and Maintenance Impacts

n/a

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

Attic/ceiling/roof insulation

Unique Measure Code: RS_SL_RTR_ATTICI_V2.0711
Effective Date: July 2011
End Date:

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[255]. Therefore if there is no insulation currently present, the R-value of 5 should be used.

Definition of Efficient Condition

The new insulation should meet any qualification criteria required for participation in the program. The new insulation R-value should include the total attic floor /roof assembly and include the effective R-value of any existing insulation that is left in situ.

Annual Energy Savings Algorithm

Savings from reduction in Air Conditioning Load:

$$\Delta kWh = ((1/Rexist – 1/Rnew) * CDH * DUA * Area) / 1{,}000 / \eta Cool$$

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[255] The R-5 assumption for roof assembly is based on J.Neymark & Associates and National Renewable Energy Laboratory, June 2009; "BESTEST-EX Interim Test Procedure" p27. The attic floor and roof should be modeled as a system including solar gains and attic ventilation, and R-5 is the standard assumption for the thermal resistance of the whole attic/roof system.

Where:

Rexist = R-value of roof assembly plus any existing insulation
= actual (minimum of R-5)
Rnew = R-value of roof assembly plus new insulation
= actual
CDH = Cooling Degree Hours[256]
= 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[257]
= 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[258]*:*

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

For example, 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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[256] 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/)

[257] 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.

[258] 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):

ΔkWh = (((1/Rexist – 1/Rnew) * HDD * 24 * Area) / 1,000,000 / ηHeat) * 293.1

HDD = *Heating Degree Days*
= *dependent on location*[259]

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*[260]*:*

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

For example, insulating 1200 square feet of attic from R-5 to R-30 in a home with a 2.5COP Heat Pump in Baltimore, MD.

ΔkWh = (((1/5 – 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 2.5) * 293.1

= 1,945 kWh

Summer Coincident Peak kW Savings Algorithm

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[259] 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.

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

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

Where:

FLHcool = *Full Load Cooling Hours*

= *Dependent on location as below:*

Location	**FLHcool**
Wilmington, DE	*513* [261]
Baltimore, MD	*531* [262]
Washington, DC	*668*

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

= *0.69* [263]

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* [264]

For example, 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.

$$\Delta kW = 120 / 531 * 0.69$$

$$= 0.16 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = ((1/Rexist - 1/Rnew) * HDD * 24 * Area) / 1{,}000{,}000 / \eta Heat$$

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[261] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying BG&E's full load hours determined for Baltimore (531 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 BG&E "Development of Residential Load Profiler for Central Air Conditioners and Heat Pumps" research.

[263] 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.

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

Where:

HDD = *Heating Degree Days*

= *dependent on location*[265]

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*[266]*. If not available use 84% for equipment efficiency and 78% for distribution efficiency to give 66%*[267]*.*

For example, insulating 1200 square feet of attic from R-5 to R-30 in a home with a 75% efficiency heating system in Baltimore, MD.

$$\Delta MMBtu = ((1/5 – 1/30) * 3457 * 24 * 1,200) / 1,000,000 / 0.75$$

$$= 22\ MMBtu$$

Annual Water Savings Algorithm

n/a

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[265] 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.

[266] 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.

[267] The equipment efficiency default is based on data provided by GAMA during the Federal rule-making process for furnace efficiency standards, suggesting that in 2000, 32% of furnaces purchased in Maryland were condensing units. Assuming an efficiency of 92% for the condensing furnaces and 80% for the non-condensing furnaces gives a weighted average of 83.8%. The distribution efficiency default is based on assumption that 50% of duct work is inside the envelope, with some leaks and no insulation. VEIC did not have any more specific data to provide any additional defaults.

Incremental Cost

The incremental cost for this 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[268].

Operation and Maintenance Impacts

n/a

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[268] 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_V1.0510
Effective Date: March 2011
End Date:

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 [269]

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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[269] Based on REMRate modeling of New Jersey baseline existing home moved to Baltimore climate with electric furnace or air source heat pump HSPF 2.0, SEER 10 AC. Ducts installed in un-conditioned basement. Duct leakage set at RESNET/HERS qualitative default.

Where:

ΔkWREM = Delta kW calculated in REMRate model
= 0.12 kW per 100 square feet window area

CF_{SSP} = Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)
= 0.69 [270]

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 [271]

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.[272]

Measure Life

The measure life is assumed to be 25 years.[273]

Operation and Maintenance Impacts

n/a

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

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

[272] Alliance to Save Energy Efficiency Windows Collaborative Report, December 2007.

[273] 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_V2.0711
Effective Date: July 2011
End Date:

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

$$\Delta kWh = kWh_{Base} - kWh_{Two\ Speed}$$ [274]

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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[274] 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

$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$ [275]

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*[276]

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*[277]

$\Delta kW_{SSP} = (1.3-0.171) * 0.20$

= 0.23 kW

$\Delta kW_{SSP} = (1.3-0.171) * 0.27$

= 0.31 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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[275] 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

[276] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[277] Ibid.

Incremental Cost

The incremental cost for this measure is assumed to be $175 for a two speed pool pump motor[278].

Measure Life

The measure life is assumed to be 10 yrs[279].

Operation and Maintenance Impacts

n/a

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[278] Based on review of Lockheed Martin pump retail price data, July 2009.

[279] VEIC estimate.

Pool pump-variable speed

Unique Measure Code: RS_PP_TOS_PPVAR_V2.0711
Effective Date: July 2011
End Date:

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

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}$$ [280]

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*

$$\Delta kWh = 707 - 113$$

---

[280] 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

$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$ [281]

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*[282]
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*[283]

$\Delta kW_{SSP} = (1.3-0.087) * 0.20$

$= 0.24$ kW

$\Delta kW_{SSP} = (1.3-0.\ 087) * 0.27$

$= 0.34$ kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

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[281] 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

[282] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16

[283] Ibid.

Incremental Cost

The incremental cost for this measure is assumed to be $750 for a variable speed pool pump motor[284].

Measure Life

The measure life is assumed to be 10 yrs[285].

Operation and Maintenance Impacts

n/a

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[284] Based on review of Lockheed Martin pump retail price data, July 2009.

[285] VEIC estimate.

Plug Load End Use

"Smart-Strip" plug outlets

Unique Measure Code: RS_PL_TOS_SMARTS_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure describes savings associated with the purchase and use of a Controlled Power Strip (or Smart Strips). 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 savings for a 5-plug strip and a 7-plug strip.

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 5 or 7-plug smart strip.

Annual Energy Savings Algorithm

$$\Delta kWh_{5\text{-}Plug} = 56.5 \text{ kWh}$$
$$\Delta kWh_{7\text{-}Plug} = 102.8 \text{ kWh}$$ [286]

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[286] NYSERDA Measure Characterization for Advanced Power Strips. Study based on review of:
i) Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.
ii) Final Field Research Report, Ecos Consulting, October 31, 2006. Prepared for California Energy Commission's PIER Program.
iii) Developing and Testing Low Power Mode Measurement Methods, Lawrence Berkeley National Laboratory (LBNL), September 2004. Prepared for California Energy Commission's Public Interest Energy Research (PIER) Program.
iv) 2005 Intrusive Residential Standby Survey Report, Energy Efficient Strategies, March, 2006.

Summer Coincident Peak kW Savings Algorithm

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

Where:

Hours = *Annual hours when controlled standby loads are turned off*
= *7,149*[287]

CF = *Coincidence Factor*
= *0.8*[288]

$$\Delta kW_{5\text{-Plug}} = (56.5/7{,}149) * 0.8$$
$$= 0.0063 \text{ kW}$$

$$\Delta kW_{5\text{-Plug}} = (102.8/7{,}149) * 0.8$$
$$= 0.012 \text{ kW}$$

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 and $26 for a 7-plug[289].

Measure Life

The measure life is assumed to be 4 years[290].

Operation and Maintenance Impacts

n/a

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v) Smart Strip Portfolio of the Future, Navigant Consulting for San Diego G&E, March 31, 2009.

[287] Average of off hours for controlled TV and computer from above study.

[288] In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

[289] NYSERDA Measure Characterization for Advanced Power Strips

[290] 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

CFL - Screw base, Retail - Commercial

Unique Measure Code(s): CI_LT_TOS_CFLSCR_V1.0510
Effective Date: May 2010
End Date:

Measure Description

A compact fluorescent light bulb (CFL) is purchased in retail and installed in a commercial location. The incremental cost of the CFL compared to an incandescent light bulb is offset via either rebate coupons or via upstream markdowns.

Definition of Baseline Condition

The baseline is the purchase and installation of an incandescent light bulb.

Definition of Efficient Condition

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

Annual Energy Savings Algorithm

$$\Delta kWh = (\Delta Watts / 1000) \times HOURS \times ISR \times WHFe$$

Where:

ΔWatts = *Compact Fluorescent Watts (if known) * 2.95* [291]

Note: The multiplier should be adjusted according to the table below to account for the change in baseline stemming from

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[291] The average wattage of the replacement CFL is 61.2W, and the average wattage of existing incandescent lamp is 15.5W. Thus, ΔWatts = [WattsEE * (WattsBASE_RLW/WattsEE_RLW)] - WattsEE = WattsEE * (3.95 - 1) = WattsEE * 2.95.:
RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

the Energy Independence and Security Act of 2007 discussed below:

CFL Wattage	**Delta Watts Multiplier**[292]			
	2009 - 2011	**2012**	**2013**	**2014 and Beyond**
15 or less	2.95	2.95	2.95	1.83
16-20	2.95	2.95	1.79	1.79
21W+	2.95	1.84	1.84	1.84

If Compact Fluorescent Watts is unknown use 45.7W [293]

Note: The delta watts should be adjusted to 30.1[294] from 2013 onwards to account for the change in baseline stemming from the Energy Independence and Security Act of 2007 discussed below.

HOURS = *Average hours of use per year*

= *If annual operating hours are unknown, see table "Interior CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information.*[295]

ISR = *In Service Rate or percentage of units rebated that get installed = 0.95* [296]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*

= *1.13* [297]

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[292] 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.

[293] RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

[294] 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. See MidAtlantic CFL Adjustments.xls for calculation.

[295] 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.

[296] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example:, assuming an office building:

$$\Delta kWh = (45.7 / 1000) \times 2{,}478 \times 0.95 \times 1.13$$

$$= 121.6 \text{ kWh}$$

Interior CFL Lighting Operating Hours and Coincidence Factors by Building Type[298]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,395	0.76	0.76
Schools	1,670	0.41	0.44
Grocery/Supermarket	3,879	0.87	0.87
Health	1,888	0.43	0.43
Hospital	4,081	0.80	0.80
Lodging – Common Area	3,984	0.43	0.43
Lodging – Guest Rooms	766	0.09	0.09
Manufacturing	1,268	0.34	0.30
Office	2,478	0.43	0.45
Other/Misc.	1,871	0.33	0.34
Restaurant	3,765	0.62	0.62
Retail	3,043	0.60	0.61
Warehouse	2,063	0.58	0.69

Note: 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).

Baseline Adjustment

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[297] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[298] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification". CFPJM refers to the

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 will require all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase out of standard incandescent bulbs. In 2012 100W incandescents will no longer be manufactured, followed by restrictions on 75W in 2013 and 60W in 2014. The baseline for this measure will therefore become bulbs (improved incandescent or halogen) that meet the new standard.

To account for these new standards, the annual savings for this measure must be reduced for 100W equivalent bulbs (21W+ CFLs) in 2012, for 75W equivalent bulbs (16-20W CFLs) in 2013 and for 60 and 40W equivalent bulbs (15W or less CFLs) in 2014. To account for this adjustment the delta watt multiplier is adjusted as shown above. In addition, since during the lifetime of a CFL, the baseline incandescent bulb will be replaced multiple times, the annual savings claim must be reduced within the life of the measure. For example, for 100W equivalent bulbs (21W+ CFLs) installed in 2010, the full savings (as calculated above in the Algorithm) should be claimed for the first two years, but a reduced annual savings claimed for the remainder of the measure life.

The appropriate adjustments as a percentage of the base year savings for each CFL range are provided below[299]:

CFL Wattage	Savings as Percentage of Base Year Savings			
	2009 - 2011	2012	2013	2014 and Beyond
15 or less	100%	100%	100%	62%
16-20	100%	100%	61%	61%
21W+	100%	63%	63%	63%

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta Watts\ /1000) \times ISR \times WHFd \times CF$$

Where:

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

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[299] Calculated by finding the percentage reduction in delta watts, for example for a 100W bulb: (72-25.3)/(100-25.3) = 62.5%. See MidAtlantic CFL Adjustments.xls for calculation.

= 1.25 [300]

CF = Summer Peak Coincidence Factor for measure
= See table "Interior CFL Lighting Operating Hours and Coincidence Factors by Building Type" above

For example, assuming an office building:

ΔkW = (45.7 / 1000) * 0.95 * 1.25 * 0.45

= 0.024 kW

Note: The savings adjustment due to the shifting baseline documented above should be applied to the peak kW savings assumed in the later years.

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) x 0.70 x 0.003413 x 0.23 / 0.75
= -ΔkWh x 0.00065

Where:

0.7 = Aspect ratio [301]

0.003413 = Constant to convert kWh to MMBTU

0.23 = Fraction of lighting heat that contributes to space heating [302]

0.75 = Assumed heating system efficiency [303]

For example, assuming an office building:

ΔMMBTU = (-121.6 / 1.13) * 0.7 * 0.003413 * 0.23 / 0.75

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[300] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[301] 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.

[302] 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).

[303] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

= -0.079 MMBtu

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $3.[304]

Measure Life

The measure life is assumed to be 3.4 years.[305]

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	$2.00
Component Life (years) (based on lamp life / assumed annual run hours)	0.29[306]	1[307]

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[304] Based on review of TRM assumptions for other States.

[305] Conservative assumption based on a typical equipment lifetime of 12,000 hours and average daily usage of 9.6 hours.

[306] Assumes rated life of incandescent bulb of 1000 hours and assumes 3,500 run hours.

[307] VEIC best estimate of future technology.

High Performance and Reduced Wattage T8 Lighting Equipment

Unique Measure Code(s): CI_LT_TOS_HPT8_V1.0510 and CI_LT_RTR_HPT8_V1.0510
Effective Date: March 2011
End Date:

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://www.cee1.org/com/com-lt/com-lt-main.php3.

For lost opportunity scenarios (i.e. time of replacement) 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 lost-opportunity 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:

Lost-opportunity: a 3-lamp standard performance 4-ft F32 T8 fixture with 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 lost-opportunity and retrofit applications are a qualifying High Performance T8 fixture and lamp/ballast combination, respectively. For illustrative purposes the following high efficiency conditions for the corresponding baselines are assumed:

Lost-opportunity: a 3-lamp High Performance T8 fixture with electronic ballast with an input wattage of 72W.

Retrofit: relamp / reballast with qualifying lamps and ballast with resulting fixture input wattage of 72W.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Connected load of baseline fixture (for "Time of Sale" or "Replacement on Burnout" 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 "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information. [308]

ISR = In Service Rate or percentage of units rebated that get installed = 0.97 [309]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.

= 1.13 [310]

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[308] 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.

[309] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

[310] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

For example, assuming an office installation:

Lost opportunity:

$$\Delta kWh = ((89 - 72) / 1000) * 2{,}567 * 0.97 * 1.13$$

$$= 47.8 \text{ kWh per fixture}$$

Retrofit:

$$\Delta kWh = ((136 - 72) / 1000) * 2{,}567 * 0.97 * 1.13$$

$$= 180.1 \text{ kWh per fixture}$$

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[311]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging – Common Area	7,884	0.90	0.90
Lodging – Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: 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).

Summer Coincident Peak kW Savings Algorithm

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[311] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in “Appendix: Weighting and Building Type Classification”.

ΔkW = ((WattsBASE – WattsEE) / 1000) x ISR x WHFd x CF

Where:

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

= 1.25 [312]

CF = Summer Peak Coincidence Factor for measure

= See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)

For example, assuming an office installation:

Lost opportunity:

ΔkW = ((89 – 72) / 1000) * 0.97 * 1.25 * 0.60

= 0.012 kW per fixture

Retrofit:

ΔkW = ((136 – 72) / 1000) * 0.97 * 1.25 * 0.60

= 0.047 kW per fixture

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) x 0.70 x 0.003413 x 0.23 / 0.75

= -ΔkWh x 0.00065

Where:

0.7 = Aspect ratio [313]

0.003413 = Constant to convert kWh to MMBTU

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[312] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[313] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

0.23 = *Fraction of lighting heat that contributes to space heating* [314]
0.75 = *Assumed heating system efficiency* [315]

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 lost opportunity and $60 for retrofit.[316]

Measure Life

The measure life is assumed to be 15 years. ("Time of Sales" or "Replacement on Burnout" measures) and 6 years ("Retrofit" measures).[317]

Operation and Maintenance Impacts

Due to differences in costs and lifetimes of replacement lamps and ballasts between the efficient and baseline cases, there are significant operation and maintenance impacts associated with this measure. Actual operation and maintenance costs will vary by specific equipment installed/replaced. For the selected examples:

Lost opportunity:	$-0.40 / year[318]
Retrofit:	$2.50 / year[319]

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[314] 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).

[315] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[316] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[317] 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, U.S. Department of Energy issued a final rule amending the energy conservation standards for general service fluorescent lamps. The standards established in the final rule will be applied starting July 14, 2012. These standards essentially require that certain linear fluorescent lamp types meet High Performance T8 specifications. For some equipment types, baseline lamps will become unavailable and participants will be required to upgrade both lamps and ballasts to High Performance T8s, thus negating any savings. Assuming a typical lamp has a lifetime of 18,000 hours and is operated approximately 3,300 hours per year, new lamps installed shortly before the impending federal standards take effect will need to be replaced in early-2017, indicating that savings should be claimed for only 6 years for measures installed in 2011.

[318] Negative value indicates cost increase.

[319] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

T5 Lighting

Unique Measure Code(s): CI_LT_TOS_T5_V1.0510 and CI_LT_RTR_T5_V1.0510
Effective Date: March 2011
End Date:

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

ΔkWh = ((WattsBASE – WattsEE) / 1000) x HOURS x ISR x WHFe

Where:

WattsBASE = Actual Connected load of baseline fixture

WattsEE = Actual Connected load of Metal Halide fixture

HOURS = Average hours of use per year

= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information. [320]

ISR = In Service Rate or percentage of units rebated that get installed = 0.97 [321]

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[320] 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.

[321] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
= *1.13* [322]

For example, a 240W T5 fixture installed in place of a 455W metal-halide in a warehouse:

$$\Delta kWh = ((455 - 240) / 1000) * 2316 * 0.97 * 1.13$$

$$= 545.8 \text{ kWh}$$

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[323]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging – Common Area	7,884	0.90	0.90
Lodging – Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: 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).

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[322] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[323] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE – WattsEE)\ /1000) \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [324]

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example:, a 240W T5 fixture installed in place of a 455W metal-halide in a warehouse:

$$\Delta kW = ((455 – 240) / 1000) * 0.97 * 1.25 * 0.55$$

$$= 0.14 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:

0.7 = *Aspect ratio* [325]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [326]
0.75 = *Assumed heating system efficiency* [327]

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[324] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floor space in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[325] 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.

[326] 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).

For example:

$$\Delta MMBTU = (-545.8 / 1.13) * 0.7 * 0.003413 * 0.23 / 0.75$$

$$= -0.35 \text{ MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $300.[328]

Measure Life

The measure life is assumed to be 15 years.[329]

Operation and Maintenance Impacts

n/a

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[327] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[328] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[329] '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

Pulse-Start Metal Halide fixture - interior

Unique Measure Code(s): CI_LT_TOS_MHFIN_V1.0510 and CI_LT_RTR_MHFIN_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure documents the electricity impacts for the installation of a high efficiency pulse-start metal halide fixture in an interior space.

Definition of Baseline Condition

The baseline condition is a mercury vapor fixture. For illustrative purposes, a 205W mercury vapor fixture (~175W lamp wattage) is assumed.

Definition of Efficient Condition

The efficient condition is a pulse-start metal halide fixture. For illustrative purposes, an 118W pulse-start metal halide fixture (~100W lamp wattage) is assumed.

Annual Energy Savings Algorithm

$$\Delta kWh = (WattsBASE - WattsEE) / 1000 \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Connected load of baseline fixture
= Actual installed
WattsEE = Connected load of Metal Halide fixture
= Actual installed
HOURS = Average hours of use per year
= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information. [330]

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[330] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

ISR = *In Service Rate or percentage of units rebated that get installed = 0.97* [331]

WHFe = *Waste Heat Factor for Energy to account for cooling savings from efficient lighting.*
13 [332]

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[333]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging – Common Area	7,884	0.90	0.90
Lodging – Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

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[331] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010Based on the in-service rate negotiated between Efficiency Vermont and the Vermont Department of Public Service; Mid-Atlantic specific value should be determined with subsequent evaluations.

[332] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.11 13 (calculated as 1 + (0.6374*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 6374% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995derived from Commercial Buildings Energy Consumption Survey 2003 data) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[333] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Note: 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).

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE)\ /1000) \times ISR \times WHFd \times CF$$

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [334]

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example, assuming a warehouse installation:

$$\Delta kW = ((205 - 118) / 1000) * 0.97 * 1.25 * 0.55$$

$$= 0.06 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:

0.7 = *Aspect ratio* [335]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [336]

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[334] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[335] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

0.75 = *Assumed heating system efficiency*[337]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $37.5.[338]

Measure Life

The measure life is assumed to be 15 years.[339]

Operation and Maintenance Impacts

n/a

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[336] 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).

[337] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[338] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[339] 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

Pulse Start Metal Halide - exterior

Unique Measure Code(s): CI_LT_TOS_MHFEX_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a pulse start metal halide in place of a standard metal halide in an exterior setting. This could relate to a time of replacement or retrofit situation.

Definition of Baseline Condition

The baseline condition is defined as a standard metal halide.

Definition of Efficient Condition

The efficient condition is defined as a pulse start metal halide.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE – WattsEE) / 1000) \times HOURS \times ISR$$

Where:

WattsBASE = *Actual Connected load of baseline fixture*
WattsEE = *Actual Connected load of pulse start metal halide fixture*
HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, assume 3,338* [340]. *Otherwise, use site specific annual operating hours information.* [341]
ISR = *In Service Rate or percentage of units rebated that get installed = 0.97* [342]

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[340] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[341] 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.

[342] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example, a 365W pulse start metal halide fixture is installed in place of a 455W standard metal halide:

$$\Delta kWh = ((455 - 365) / 1000) * 3,338 * 0.97$$

$$= 291.4 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = ((WattsBASE - WattsEE) /1000) \times ISR \times CF$$

Where:

CF = Summer Peak Coincidence Factor for measure

= 0.037 [343]

For example:

$$\Delta kW = ((455 - 365) / 1000) * 0.97 * 0.037$$

$$= 0.003 \text{ kW}$$

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 $37.50.[344]

Measure Life

The measure life is assumed to be 15 years.[345]

Operation and Maintenance Impacts

n/a

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[343] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[344] Ibid.

[345] '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 Pressure Sodium

Unique Measure Code(s): CI_LT_TOS_SODIUM_V1.0510 and CI_LT_RTR_SODIUM_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure relates to the installation of a High Pressure Sodium fixture in an exterior location.

Definition of Baseline Condition

The baseline condition is a quartz halogen lamp.

Definition of Efficient Condition

The efficient condition is a high-pressure sodium lamp.

Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR$$

Where:

WattsBASE = *Actual Connected load of baseline fixture*
WattsEE = *Actual Connected load of HPT8 fixture*
HOURS = *Average hours of use per year*
= *If annual operating hours are unknown, assume 3,338* [346]. *Otherwise, use site specific annual operating hours information.* [347]
ISR = *In Service Rate or percentage of units rebated that get installed = 0.97* [348]

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[346] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey.

[347] 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.

[348] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example, a 90W high pressure sodium lamp installed in place of a 200W quartz halogen lamp:

ΔkWh = ((200 – 90) / 1000) * 3,338 * 0.97

=356.1 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((WattsBASE – WattsEE) /1000) x ISR x CF

Where:

CF = *Summer Peak Coincidence Factor for measure*
= *0.0374* [349]

For example:

ΔkW = ((200 – 90) / 1000) * 0.97 * 0.0374

= 0.0040 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 $30.[350]

Measure Life

The measure life is assumed to be 15 years.[351]

Operation and Maintenance Impacts

n/a

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[349] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

[350] Ibid.

[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

LED Exit Sign

Unique Measure Code(s): CI_LT_RTR_LEDEXI_V1.0510
Effective Date: May 2010
End Date:

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

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times ISR \times WHFe$$

Where:

WattsBASE = Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.[352]
WattsEE = Actual Connected load of LED exit sign
HOURS = Average hours of use per year
= 8,760 [353]
ISR = In Service Rate or percentage of units rebated that get installed = 0.97 [354]
WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.
= 1.13 [355]

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[352] 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.

[353] Assumes operation 24 hours per day, 365 days per year.

[354] EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

For example a 5W LED lamp in place of a 16W CFL:

ΔkWh = ((16 – 5) / 1000) * 8,760 * 0.97 * 1.13

= 105.6 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (WattsBASE - WattsEE) / 1000 x ISR x WHFd x CF

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [356]

CF = *Summer Peak Coincidence Factor for measure*
= *1.0* [357]

For example:

ΔkW = ((16 – 5) / 1000) * 0.97 * 1.25 * 1.0

= 0.013 kW

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) x 0.70 x 0.003413 x 0.23 / 0.75
= -ΔkWh x 0.00065

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[355] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[356] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[357] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

Where:

0.7 = *Aspect ratio* [358]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [359]

0.75 = *Assumed heating system efficiency* [360]

For example:

$$\Delta\text{MMBTU} = (-105.6/\ 1.13) * 0.7 * 0.003413 * 0.23\ /\ 0.75$$

$$= -0.069\ \text{MMBtu}$$

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $35.[361]

Measure Life

The measure life is assumed to be 7 years.[362]

Operation and Maintenance Impacts

n/a

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[358] 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.

[359] 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).

[360] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[361] Represents the full installed cost of an LED exit sign. LED exit signs can typically be purchased for ~$25 (see http://www.exitlightco.com/Exit_Signs and "http://www.simplyexitsigns.com"). Assuming replacing exit sign requires 15 minutes of a common building laborer's time in Washington D.C. (RSMeans Electrical Cost Data 2008), the total installed cost would be approximately $35.

[362] 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.

Solid State Lighting (LED) Recessed Downlight

Unique Measure Code: CI_LT_TOS_SSLDWN_V2.0711, CI_LT_RTR_SSLDWN_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of an ENERGY STAR v1.3 qualified commercial LED recessed downlight in place of a standard efficiency lighting technology[363]. This measure could be either a lost-opportunity 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 v1.3 qualified commercial LED recessed downlight listed on the ENERGY STAR Qualified LED Lighting list[364].

Annual Energy Savings Algorithm

For **lost-opportunity** installations:

ΔkWh = [(WattsEE * (WattsBASE$_{typ}$/WattsEE$_{typ}$) – WattsEE) / 1000] * ISR * HOURS * WHF$_e$

= [((WattsEE * 3.08) – WattsEE) / 1000] * ISR * HOURS * WHF$_e$

For **retrofit** installations:

ΔkWh = [(WattsBASE – WattsEE) / 1000] * ISR * HOURS * WHF$_e$

Where:

WattsEE = Connected load of LED recessed downlight
= Actual Installed [W]
WattsBASE$_{typ}$ = typical baseline wattage; assumed as 54.8W[365]

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[363] See http://www.energystar.gov/ia/partners/product_specs/program_reqs/Solid-State_Lighting_Program_Requirements.pdf

[364] The list can be found here: http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_com_pdf

[365] Based on 2008-2010 Efficiency Vermont historical data of 835 installed measures

$WattsEE_{typ}$ = typical wattage of the LED recessed downlight; assumed as 17.8W[366]

WattsBASE = Connected load of the baseline light fixture
= Actual Installed [W]

ISR = 0.97[367]

HOURS = Average hours of use per year
= If annual operating hours are unknown, see table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information[368]*.*

WHF_e = Waste heat factor(energy) to account for space cooling energy saving due to the generation of reduced lighting waste heat.
= 1.13[369]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = [(WattsBASE - WattsEE) / 1{,}000] \times ISR \times WHF_d \times CF$$

Where:

WHF_d = Waste heat factor(demand) to account for space cooling demand saving due to the generation of reduced lighting waste heat.
= 1.25[370]

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[366] Based on 2008-2010 Efficiency Vermont historical data of 835 installed measures

[367] "Verification of Reported Energy and Peak Savings from the EmPOWER Maryland Energy Efficiency Programs," Itron, Inc., March 2011.

[368] 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.

[369] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[370] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of

CF = *Summer Peak Coincidence Factor for measure*
= *See "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" table in the "Reference Tables" section.*

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times Aspect\ Ratio \times 0.003413 \times Heating\ Fraction / \eta_{Heat}$$

$$= -\Delta kWh \times 0.00065$$

Where:

Aspect Ratio = 0.70[371]

0.003413 = *MMBtu/kWh unit conversion factor*

Heating Fraction (lighting heat that contributes to space heating)
= 0.23[372]

η_{Heat} = 0.75[373]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $80[374] for lost-opportunity installations. Custom incremental costs should be calculated for retrofit installations.

Measure Life

The measure life is assumed to be 10 years[375].

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lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[371] 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.

[372] 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).

[373] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[374] Efficiency Vermont Technical Reference User Manual No. 2010-67a

[375] 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).

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[376]:

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 is $93.45.

Reference Tables

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[377]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80

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[376] Efficiency Vermont Technical Reference User Manual No. 2010-67a

[377] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in “Appendix: Weighting and Building Type Classification”.

Building Type	**HOURS**	**CF_{PJM}**	**CF_{SSP}**
Lodging – Common Area	7,884	0.90	0.90
Lodging – Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: 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).

Delamping

Unique Measure Code(s): CI_LT_ERT_DELAMP_V1.0510
Effective Date: May 2010
End Date:

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

$$\Delta kWh = ((WattsBASE - WattsEE) / 1000) \times HOURS \times WHFe$$

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 "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" below. Otherwise, use site specific annual operating hours information. [378]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.

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[378] 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.

= 1.13 [379]

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[380]

Building Type	**HOURS**	**CF_{PJM}**	**CF_{SSP}**
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging – Common Area	7,884	0.90	0.90
Lodging – Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

Note: 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).

Summer Coincident Peak kW Savings Algorithm

ΔkW = ((WattsBASE – WattsEE) /1000) x WHFd x CF

Where:

WHFd = Waste Heat Factor for Demand to account for cooling savings from efficient lighting
= 1.25 [381]

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[379] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[380] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example, one lamp of a three lamp 4ft T8 Fixture (89W) is removed (leaving 67W) in an office:

$$\Delta kW = ((89 - 67) / 1000) * 1.25 * 0.60$$

$$= 0.017 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) \times 0.70 \times 0.003413 \times 0.23 / 0.75$$
$$= -\Delta kWh \times 0.00065$$

Where:
0.7 = *Aspect ratio* [382]
0.003413 = *Constant to convert kWh to MMBTU*
0.23 = *Fraction of lighting heat that contributes to space heating* [383]
0.75 = *Assumed heating system efficiency* [384]

Annual Water Savings Algorithm

n/a

Incremental Cost

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[381] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[382] 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.

[383] 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).

[384] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

The incremental cost for this measure is assumed to be $10.8 per fixture.[385]

Measure Life

The measure life is assumed to be 15 years.[386]

Operation and Maintenance Impacts

Delamping reduces the number of periodic lamp replacements required, saving $1.25/year.

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[385] 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.

[386] 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 box

Unique Measure Code(s): CI_LT_TOS_OSWALL_V1.0510
Effective Date: March 2011
End Date:

Measure Description

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

Definition of Baseline Condition

The baseline condition is lighting that is not controlled with an occupancy sensor.

Definition of Efficient Condition

The efficient condition is lighting that is controlled with an occupancy sensor.

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 before control
= If annual operating hours are unknown, see table “Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type” below. Otherwise, use site specific annual operating hours. [387]
SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.

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[387] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. In most cases, it should not be assumed that the lighting hours of operation are identical to the reported operating hours for the business. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment.

= 0.3 [388]

ISR = In Service Rate or percentage of units rebated that get installed = 0.98 [389]

WHFe = Waste Heat Factor for Energy to account for cooling savings from efficient lighting.

= 1.13 [390]

Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type[391]

Building Type	HOURS	CF_{PJM}	CF_{SSP}
College	2,348	0.76	0.76
Schools	1,632	0.31	0.28
Grocery/Supermarket	4,660	0.87	0.87
Health	3,213	0.73	0.76
Hospital	5,182	0.80	0.80
Lodging – Common Area	7,884	0.90	0.90
Lodging – Guest Rooms	914	0.09	0.09
Manufacturing	2,980	0.57	0.53
Office	2,567	0.61	0.60
Other/Misc.	1,797	0.34	0.32
Restaurant	3,613	0.65	0.67
Retail	2,829	0.73	0.76
Warehouse	2,316	0.54	0.55

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[388] Quantum Consulting, Inc., for Pacific Gas & Electric Company, Evaluation of Pacific Gas & Electric Company's 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies, March 1, 1999.

[389] Based on the in-service rate negotiated between Efficiency Vermont and the Vermont Department of Public Service; Mid-Atlantic specific value should be determined with subsequent evaluations.

[390] Waste heat factor to account for cooling energy savings from efficient lighting. For a cooled space, the value is 1.13 (calculated as 1 + (0.74*(0.45) / 2.5)). Based on 0.45 ASHRAE Lighting waste heat cooling factor for Washington DC and estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995) with 2.5 C.O.P. typical cooling system efficiency (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[391] Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010. Additional discussion on building type weighting methodology can be found in "Appendix: Weighting and Building Type Classification".

Note: 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).

Summer Coincident Peak kW Savings Algorithm

ΔkW = kWconnected x SVG x ISR x WHFd x CF

Where:

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting*
= *1.25* [392]

CF = *Summer Peak Coincidence Factor for measure*
= *See table "Interior Non-CFL Lighting Operating Hours and Coincidence Factors by Building Type" above)*

For example a 400W connected load being controlled in an office:

ΔkW = 0.4 * 0.3 * 0.98 * 1.25 * 0.60

= 0.09 kW

Annual Fossil Fuel Savings Algorithm

Note: Negative value denotes *increased* fossil fuel consumption.

ΔMMBTU = (-ΔkWh / WHFe) x 0.70 x 0.003413 x 0.23 / 0.75
= -ΔkWh x 0.00065

Where:

0.7 = *Aspect ratio* [393]

0.003413 = *Constant to convert kWh to MMBTU*

0.23 = *Fraction of lighting heat that contributes to space heating* [394]

---

[392] Waste heat factor to account for cooling demand savings from efficient lighting. For a cooled space, the value is 1.25 (calculated as 1 + (0.74*(0.85) / 2.5)). Based on 2.5 COP cooling system efficiency, estimate that 74% of commercial floorspace in the Mid-Atlantic region is cooled (Delmarva Commercial Baseline Research Project, Final Report, SAIC, 1995), and 85% of lighting heat that needs to be mechanically cooled at time of summer peak (methodology adopted from ASHRAE Journal, Calculating Lighting and HVAC Interactions, 1993).

[393] HVAC-Lighting interaction impacts adapted from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions. Typical aspect ratio for perimeter zones. Heating factor applies to perimeter zoneheat, therefore it must be adjusted to account for lighting in core zones.

0.75 = *Assumed heating system efficiency* [395]

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $55.[396]

Measure Life

The measure life is assumed to be 10 years.[397]

Operation and Maintenance Impacts

n/a

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[394] 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).

[395] Typical heating system efficiency of 75%, consistent with current federal standards for fossil fuel-fired systems.

[396] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

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

Heating Ventilation and Air Conditioning (HVAC) End Use

High Efficiency Unitary AC - Existing

Unique Measure Code(s): CI_HV_TOS_UNIA/C_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure documents savings associated with the installation of new split or packaged unitary air conditioning systems meeting defined efficiency criteria.

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)[398].

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 efficiency standards as defined below (see table "Baseline and Efficient Efficiency Levels by Unit Capacity" below).

Baseline and Efficient Efficiency Levels by Unit Capacity

Equipment Type	Size Category	Subcategory	Baseline Condition (IECC 2009)	Efficiency Condition (CEE Tier I)
Air Conditioners, Air Cooled	<65,000 Btu/h	Split system	13.0 SEER	14.0 SEER 12.0 EER
		Single package	13.0 SEER	14.0 SEER 11.6 EER
	≥65,000 Btu/h and <135,000 Btu/h	Split system and single package	11.0 EER 11.2 IEER	11.5 EER TBD IEER
	≥135,000 Btu/h and <240,000 Btu/h	Split system and single package	10.8 EER 11.0 IEER	11.5 EER TBD IEER

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[398] Integrated Energy Efficiency Ratio (IEER) requirements have been incorporated from ASHRAE 90.1-2007, "Energy Standard for Buildings Except Low-Rise Residential Buildings". IECC 2009 does not present IEER requirements.

Equipment Type	Size Category	Subcategory	Baseline Condition (IECC 2009)	Efficiency Condition (CEE Tier I)
	≥240,000 Btu/h and <760,000 Btu/h	Split system and single package	9.8 EER 9.9 IEER	10.5 EER TBD IEER
	≥760,000 Btu/h	Split system and single package	9.5 EER 9.6 IEER	9.7 EER TBD IEER

Notes: 1) All table baseline efficiency ratings assume a non-electric resistance heating section type. If electric resistance heating section (or no heating section), subtract 0.2 from each baseline efficiency rating value. 2) To date, the Consortium for Energy Efficiency (CEE) has not published efficiency requirements in terms of the Integrated Energy Efficiency Ratio (IEER). When a new specification is released, this table should be updated.

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:

ΔkWh = (Btu/hour/1000) x [(1/SEERBASE - 1/SEEREE)] x HOURS

For units with capacities greater than or equal to 65,000 Btu/h, the energy savings are calculated using the Energy Efficiency Ratio (EER) as follows:

ΔkWh = (Btu/hour/1000) x [(1/EERBASE - 1/EEREE)] x 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, assume 848 (default) [399]. *Otherwise, use site specific full load cooling hours information.*

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[399] BG&E Development of Commercial Load Profiler for Central Air Conditioners and Heat Pumps, Version 2. 3/2/10; 848 full load cooling hours.

For example, a 5 ton unit with SEER rating of 14.0:

ΔkWh = (60,000/1000) * (1/13 – 1/14) * 848

= 279.6 kWh

Summer Coincident Peak kW Savings Algorithm

ΔkW = (Btu/hour/1000) x [(1/EERBASE - 1/EEREE)] x 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
CF_{PJM} *=PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= 0.808 [400]
CF_{SSP} *= Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= 0.923 [401]

For example, a 5 ton unit with EER rating of 12:[402]

ΔkW = (60,000/1000) * (1/10.8 – 1/12) * 0.808

= 0.45 kW

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

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[400] 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.

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

[402] Assumes baseline unit with 13 SEER converted to EER using the following estimate: EER = SEER/1.2

The incremental cost for this measure is assumed to be \$100 per ton for units with capacities less than 65,000 Btu/h and \$120 per ton for units with capacities greater than or equal to 65,000 Btu/h.[403]

Measure Life

The measure life is assumed to be 15 years.[404]

Operation and Maintenance Impacts

n/a

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[403] 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.

[404] 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)

Unique Measure Code(s): CI_MO_TOS_VFDRIVE_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure defines savings associated with installing a Variable Frequency Drive on a motor of 10 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, 10HP or less, without a VFD control.

Definition of Efficient Condition

The efficient condition is a motor, 10HP or less, with a VFD control.

Annual Energy Savings Algorithm

$$\Delta kWh = [(HP \times 0.746) / \eta BASE] \times HOURS \times ESF$$

Where:

HP = *Motor Horse Power*
= *Actual controlled motor horse power*
0.746 = *kWh per HP conversion factor*
ηBASE = *Efficiency of baseline 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)*

For example, a 10HP motor with VFD used on supply fan application in an office (assume 90% motor efficiency and constant volume baseline control):

$$\Delta kWh = [(10 * 0.746) / 0.9] * 3{,}748 * 0.717$$

$$= 22{,}280 \text{ kWh}$$

VFD Operating Hours by Application and Building Type[405]

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Auto Related	4,056	1,878	6,000
Bakery	2,854	1,445	6,000
Banks, Financial Centers	3,748	1,767	6,000
Church	1,955	1,121	6,000
College – Cafeteria	6,376	2,713	6,000
College - Classes/Administrative	2,586	1,348	6,000
College - Dormitory	3,066	1,521	6,000
Commercial Condos	4,055	1,877	6,000
Convenience Stores	6,376	2,713	6,000
Convention Center	1,954	1,121	6,000
Court House	3,748	1,767	6,000
Dining: Bar Lounge/Leisure	4,182	1,923	6,000
Dining: Cafeteria / Fast Food	6,456	2,742	6,000
Dining: Family	4,182	1,923	6,000
Entertainment	1,952	1,120	6,000
Exercise Center	5,836	2,518	6,000
Fast Food Restaurants	6,376	2,713	6,000
Fire Station (Unmanned)	1,953	1,121	6,000
Food Stores	4,055	1,877	6,000
Gymnasium	2,586	1,348	6,000
Hospitals	7,674	3,180	6,000
Hospitals / Health Care	7,666	3,177	6,000
Industrial - 1 Shift	2,857	1,446	6,000
Industrial - 2 Shift	4,730	2,120	6,000
Industrial - 3 Shift	6,631	2,805	6,000
Laundromats	4,056	1,878	6,000
Library	3,748	1,767	6,000
Light Manufacturers	2,857	1,446	6,000
Lodging (Hotels/Motels)	3,064	1,521	6,000
Mall Concourse	4,833	2,157	6,000
Manufacturing Facility	2,857	1,446	6,000
Medical Offices	3,748	1,767	6,000
Motion Picture Theatre	1,954	1,121	6,000

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[405] UI and CL&P Program Savings Documentation for 2009 Program Year, October 2008.

Multi-Family (Common Areas)	7,665	3,177	6,000
Museum	3,748	1,767	6,000
Nursing Homes	5,840	2,520	6,000
Office (General Office Types)	3,748	1,767	6,000
Office/Retail	3,748	1,767	6,000
Parking Garages & Lots	4,368	1,990	6,000
Penitentiary	5,477	2,389	6,000
Performing Arts Theatre	2,586	1,348	6,000
Police / Fire Stations (24 Hr)	7,665	3,177	6,000
Post Office	3,748	1,767	6,000
Pump Stations	1,949	1,119	6,000
Refrigerated Warehouse	2,602	1,354	6,000
Religious Building	1,955	1,121	6,000
Residential (Except Nursing Homes)	3,066	1,521	6,000
Restaurants	4,182	1,923	6,000
Retail	4,057	1,878	6,000
School / University	2,187	1,205	6,000
Schools (Jr./Sr. High)	2,187	1,205	6,000
Schools (Preschool/Elementary)	2,187	1,205	6,000
Schools (Technical/Vocational)	2,187	1,205	6,000
Small Services	3,750	1,768	6,000
Sports Arena	1,954	1,121	6,000
Town Hall	3,748	1,767	6,000
Transportation	6,456	2,742	6,000
Warehouse (Not Refrigerated)	2,602	1,354	6,000
Waste Water Treatment Plant	6,631	2,805	6,000
Workshop	3,750	1,768	6,000

Energy and Demand Savings Factors[406]

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

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[406] UI and CL&P Program Saving Documentation for 2009 Program Year; energy and demand savings constants were derived using a temperature BIN spreadsheet and typical heating, cooling and fan load profiles.

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

Summary Coincident Peak kW Savings Algorithm

$$\Delta kW = [(HP \times 0.746) / \eta BASE] \times DSF \times CF$$

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) [407]

For example, a 10HP motor with VFD used on supply fan application in an office (assume 90% motor efficiency and constant volume baseline control):

$$\Delta kW = [(10 /* 0.746)/ 0.9] * 0.466 * 0.28$$

$$= 1.08 \text{ kW}$$

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure varies by controlled motor hp. See table "VFD Incremental Costs" below.

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[407] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives – Pumps.

VFD Incremental Costs[408]

HP	Fan	Pump
5	$920	$1,710
7.5	$1,310	$2,100
10	$1,320	$2,150

Measure Life

The measure life is assumed to be 15 years for HVAC applications.[409]

Operation and Maintenance Impacts

n/a

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[408] UI and CL&P Program Savings Documentation for 2009 Program Year, October 2008.

[409] Efficiency Vermont Technical Reference Manual 2009-55, December 2008.

Electric Chillers

Unique Measure Code: CI_HV_TOS_ELCHIL_V2.0711, CI_HV_RTR_ELCHIL_V2.0711,
Effective Date: July 2011
End Date:

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 could relate to either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

Lost-Opportunity: 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).

Retrofit: The baseline condition is an existing water chilling package.

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

ΔkWh = TONS * (IPLVbase - IPLVee) * HOURS

Where:

TONS = Total installed capacity of the water chilling package[tons]
= Actual Installed
IPLVbase = Integrated Part Load Value (IPLV)[410] *of the baseline equipment [kW/ton]*
= For lost-opportunity: Varies by equipment type and capacity. See “Lost-Opportunity Baseline Equipment

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[410] Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

Efficiency" table in the "Reference Tables" section below[411]
= For retrofit: the actual IPLV of the existing equipment

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

$$\Delta kW = TONS \times (Full\_Loadbase - Full\_Loadee) \times CF$$

Where:

Full_Loadbase = Full load efficiency of the baseline equipment [kW/ton]
= For lost-opportunity: Varies by equipment type and capacity. See "Lost-Opportunity Baseline Equipment Efficiency" table in the "Reference Tables" section below[412]
= For retrofit: the actual full load efficiency of the existing equipment

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[413]

CF_{SSP} *= Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= 0.923[414]

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[411] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

[412] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

[413] 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.

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

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be custom.

Measure Life

The measure life is assumed to be 23 years[415].

Operation and Maintenance Impacts

n/a

Reference Tables

Lost-Opportunity Baseline Equipment Efficiency[416]

Equipment Type	Size Category	Units	Path A[a]		Path B[a]	
			Full Load	IPLV	Full Load	IPLV
Air-Cooled Chillers	<150 tons	EER	≥9.562	≥12.500	NA	NA
	≥150 tons	EER	≥9.562	≥12.750	NA	NA
Water Cooled, Electrically Operated, Positive Displacement	<75 tons	kW/ton	≤0.780	≤0.630	≤0.800	≤0.600
	≥75 tons and <150 tons	kW/ton	≤0.775	≤0.615	≤0.790	≤0.586
	≥150 tons and <300 tons	kW/ton	≤0.680	≤0.580	≤0.718	≤0.540
	≥300 tons	kW/ton	≤0.620	≤0.540	≤0.639	≤0.490
Water Cooled, Electrically Operated, Centrifugal	<150 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥150 tons and <300 tons	kW/ton	≤0.634	≤0.596	≤0.639	≤0.450
	≥300 tons and <600 tons	kW/ton	≤0.576	≤0.549	≤0.600	≤0.400
	≥600 tons	kW/ton	≤0.570	≤0.539	≤0.590	≤0.400

a. Compliance with IECC 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.

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[415] 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"

[416] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(7) Water Chilling Packages, Efficiency Requirements.

Default Electric Chiller Full Load Cooling Hours[417]

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
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

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[417] 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.**
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_V2.0711, CI_HV_RTR_GASBLR_V2.0711

Effective Date: July 2011

End Date:

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 could be either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

Lost-Opportunity: The baseline condition is a gas boiler equal to the requirements presented in the International Energy Conservation Code 2009 (IECC 2009). See the “Lost-Opportunity Baseline Equipment Efficiency” table in the “Reference Tables” section

Retrofit: The baseline condition is an existing gas boiler

Definition of Efficient Condition

The efficient condition is a high-efficiency gas boiler exceeding the requirements presented in the International Energy Conservation Code 2009 (IECC 2009). See the “Lost-Opportunity 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

$$\Delta \text{MMBtu} = \text{CAP x HOURS x } (1/\text{EFF}_{base} - 1/\text{EFF}_{ee}) / 1{,}000{,}000$$

Where:

CAP = Equipment capacity [Btu/h]
= Actual Installed

HOURS = *Full Load Heating Hours*
= See "Heating Full Load Hours" table in the "Reference Tables" section below[418]
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 lost-opportunity: See "Lost-Opportunity Baseline Equipment Efficiency" table in the "Reference Tables" section below[419]
= For retrofit: the actual efficiency of the existing 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 is assumed to be \$0.012 per Btu/h for units <300,000 Btu/h and \$0.10 per Btu/h for units >= 300,000 Btu/h[420].

Measure Life

The measure life is assumed to be 20 years[421].

Operation and Maintenance Impacts

n/a

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[418] 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.

[419] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[420] Incremental Cost based on analysis of proprietary vendor data from models such as MicoFlame, DynaFlame, NY Thermal, Patterson Kelley and more, 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.

[421] Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

Reference Tables

Lost-Opportunity Baseline Equipment Efficiency[422]

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency
Boilers, Gas-fired	<300,000 Btu/h	Hot water	80% AFUE
		Steam	75% AFUE
	>=300,000 Btu/h and <=2,500,000 Btu/h	Minimum capacity	75% E_t and 80% E_c
	>2,500,000 Btu/h	Hot water	80% E_c
		Steam	80% E_c

Heating Full Load Hours[423]

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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[422] Baseline efficiencies based on International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[423] 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_V2.0711, CI_HV_RTR_GASFUR_V2.0711
Effective Date:
End Date:

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 could be either a lost-opportunity or retrofit installation.

Definition of Baseline Condition

Lost-Opportunity: The baseline condition is a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 80% with a standard efficiency furnace fan.

Retrofit: The baseline condition is an existing gas furnace.

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[424]

ΔkWh = 733 kWh[425]

Summer Coincident Peak kW Savings Algorithm

ΔkW = 0.19 kW[426]

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[424] Energy and Demand Savings come from the ECM furnace fan motor. These motors are also available as a separate retrofit on an existing furnace.

[425] 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.

[426] Efficiency Vermont Technical Reference User Manual No. 2010-67a. Measure Number I-A-6-a.

Annual Fossil Fuel Savings Algorithm

$$\Delta MMBtu = CAP \times HOURS \times [(1/AFUE_{base}) - (1/AFUE_{ee})] / 1,000,000$$

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[427]

$AFUE_{base}$ *= Annual Fuel Utilization Efficiency of the baseline equipment*
= For lost-opportunity: 0.80[428]
= For retrofit: the actual AFUE of the existing equipment

$AFUE_{ee}$ *= 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[429].

Measure Life

The measure life is assumed to be 18 years[430].

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[427] 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.

[428] 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.

[429] 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.

Operation and Maintenance Impacts

n/a

Reference Tables

Heating Full Load Hours[431]

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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[430] 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"

[431] 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_V2.0711
Effective Date: July 2011
End Date:

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, without dual enthalpy economizer controls.

Definition of Efficient Condition

The efficient condition is the HVAC system with dual enthalpy economizer controls.

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[432]

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0 \ kW$$[433]

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[432] kWh/ton savings from "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", TecMarket Works, October 15, 2010, scaled based on enthalpy data from New York City and Mid-Atlantic cities from Typical Meteorological Year 3 (TMY3) data published by the National Renewable Energy Laboratory.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost

The incremental cost for this measure is assumed to be $400 for a dry bulb economizer baseline and $800 for a fixed damper baseline[434].

Measure Life

The measure life is assumed to be 10 years[435].

Operation and Maintenance Impacts

n/a

Reference Tables

Savings Factors[436]

Savings Factors (kWh/ton)	Dover, DE	Wilmington, DE	Baltimore, MD	Hagerstown, MD	Patuxent River, MD	Salisbury, MD	Washington D.C.
Assembly	26	22	25	29	25	27	25
Big Box Retail	144	125	143	165	141	155	139
Fast Food	37	32	37	42	36	40	36
Full Service Restaurant	29	25	29	34	29	32	28
Light Industrial	24	21	23	27	23	25	23
Primary School	40	34	39	45	39	43	39
Small Office	177	153	175	201	173	189	171
Small Retail	90	78	89	103	88	97	87
Religious	6	5	6	6	6	6	6
Warehouse	2	2	2	2	2	2	2
Other	58	50	57	66	57	62	56

---

[433] Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

[434] Cost ranges from $250-$400 when going from a dry bulb economizer baseline; only one source gives cost of going from a fixed damper baseline ($800)

[435] General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

[436] kWh/ton savings from NY Standard Approach Model, with scaling factors based on enthalpy data from NYC and Mid-Atlantic cities.

Refrigeration End Use

Efficient Freezer

Unique Measure Code(s): CI_RF_TOS_FREEZER_V1.0510
Effective Date: March 2011
End Date:

Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency packaged commercial reach-in freezer, typically used by foodservice establishments.

Definition of Baseline Condition

The baseline condition is a standard-efficiency packaged commercial reach-in freezer.

Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified, high-efficiency packaged commercial reach-in freezer.

Annual Energy Savings Algorithm

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) \times 365$$

Where:

$kWhBASEdailymax$ [437] $= 0.40V+1.38$ (solid door)
$= 0.75V+4.10$ (glass door)

$kWhEEdailymax$ [438]

Solid Door Cabinets:

$0<V<15$: $<=0.250V+1.250$
$15<=V<30$: $<=0.400V-1.000$
$30<=V<50$: $<=0.163V+6.125$

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[437] Nadel, S. Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, 12/2002.

[438] High Efficiency Specifications for Commercial Refrigerators and Freezers, Consortium for Energy Efficiency, 1/1/2010.

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: <=0.250+13.5000
50<=V: <=0.450V+3.500

Chest Configuration:
Solid or Glass Door Cabinets:
<=0.270V+0.130

V = Association of Home Appliances Manufacturers (AHAM) volume

For example, for a 50 ft^2 solid door refrigeration unit:

$$\Delta kWh = ((0.4*50+1.38)-(0.158*50+6.333))*365$$

$$= 2608.7 \text{ kWh}$$

Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (\Delta kWh/HOURS) \times CF$$

Where:

HOURS = Full load hours
= 5858 [439]
CF = Summer Peak Coincidence Factor for measure
= 0.772 [440]

For example, for a 50 ft^2 solid door refrigeration unit:

$$\Delta kW = (2608.7 / 5858) * 0.772$$

$$= 0.34 \text{ kW}$$

---

[439] Efficiency Vermont Estimate, Derived from Washington Electric Coop data by West Hill Energy Consultants.

[440] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York. Combined with full load hour assumptions used for efficiency measures to account for diversity of equipment usage within the peak period hours.

Annual Fossil Fuel Savings Algorithm

n/a

Annual Water Savings Algorithm

n/a

Incremental Cost [441]

The incremental cost for this measure is assumed to be:

0<V<=32: $150
32<V<=60: $200
60<=V<80: $250.

Measure Life

The measure life is assumed to be 9 years.[442]

Operation and Maintenance Impacts

n/a

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[441] Nadel, S. Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, 12/2002.

[442] Energy Savings Potential for Commercial Refrigeration Equipment, Arthur D. Little, Inc., 1996.

Hot Water End Use

C&I Heat Pump Water Heater

Unique Measure Code(s): CI_WT_TOS_HPCIHW_V1.0510
Effective Date: May 2010
End Date:

Measure Description

This measure relates to the installation of a Heat Pump water heater in place of a standard electric water heater. This measure could relate to either a retrofit or a new installation.

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

$$\Delta kWH = (kBtu\_req / 3.413) \times ((1/EFbase) - (1/EFee))$$

Where:

kBtu_req (Office) = Required annual heating output of office (kBtu)
= 6,059 [443]
kBtu_req (School) = Required annual heating output of school (kBtu)
= 22,191 [444]

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[443] 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.

[444] 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* [445]
EFbase = *Energy Factor of baseline domestic water heater*
= *0.904* [446]
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 x 8.33 x 1.0 x WaterTempRise x 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*
= *5885* [447]
Hours (School) = *Run hours in school*
= *2218* [448]

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[445] 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

[446] Ibid.

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

[448] Ibid.

CF (Office) measure = *Summer Peak Coincidence Factor for office*
= *0.630* [449]

CF (School) measure = *Summer Peak Coincidence Factor for school*
= *0.580* [450]

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.[451]

Measure Life

The measure life is assumed to be 10 years.[452]

Operation and Maintenance Impacts

n/a

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[449] Ibid.

[450] Ibid.

[451] 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

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

Plug Load End Use

"Smart-Strip" plug outlets

Unique Measure Code: CI_PL_TOS_SMARTS_V2.0711
Effective Date: July 2011
End Date:

Measure Description

This measure relates to the installation of a "smart-strip" plug outlet 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 lost-opportunity 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 "smart-strip" plug outlet 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 "smart strip" detects that a controlling device, or master load, has been switched off. The efficient device effectively eliminates standby power consumption (phantom power) for all controlled devices[453] when the master load is not in use.

Annual Energy Savings Algorithm

$\Delta kWh = 24\ kWh$[454]

Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0\ kW$[455]

Annual Fossil Fuel Savings Algorithm

n/a

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[453] Most "smart-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.

[454] Deemed savings from "State of Ohio Energy Efficiency Technical Reference Manual", Vermont Energy Investment Corporation, August 2010.

[455] Deemed savings from "State of Ohio Energy Efficiency Technical Reference Manual", Vermont Energy Investment Corporation, August 2010.

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[456].

Measure Life

The measure life is assumed to be 4 years[457].

Operation and Maintenance Impacts

n/a

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[456] NYSERDA Measure Characterization for Advanced Power Strips

[457] 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. Clothes Washer Calculation Sheet
2. 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

Clothes Washer Work Sheet - ENERGY STAR and CEE TIER 3

1. Calculate kWh savings per year per machine:

kWh Savings per machine = Washer Volume* (1/BaseMEF - 1/EFFMEF) * # Cycles

ENERGY STAR 2010	217.2
ENERGY STAR 2011	267.9
CEE TIER 3	309.3

Where:		Source:
Washer Volume	3.23	Average of in VT program
Base MEF	1.26	Federal Standard
ESTAR 2010 MEF	1.8	Energy Star minimum standard
ESTAR 2010 MEF	2	New Energy Star minimum standard
CEE TIER 3 MEF	2.2	CEE Tier 3 Standard
# Cycles	282	Weighted average of 2005 Residential Energy Consumption Survey (RECS) for Mid Atlantic. http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hc10homeappliaceindicators/pdf/tablehc11.10.pdf

2. Divide savings by end use for washer and dryer operation:

		ENERGY STAR 2010			ENERGY STAR 2011			CEE TIER 3		
Electricity Consumption by End Use for Washer/Dryer Operation	Electricity Consumption Percent by End Use	Electric	Gas	Oil	Electric	Gas	Oil	Electric	Gas	Oil
Water Heating	26%	56.5	0.24	0.24	69.6	0.30	0.30	80.4	0.34	0.34
CW Machine Operation	7%	15.2	n/a	n/a	18.8	n/a	n/a	21.7	n/a	n/a
Dryer	67%	145.5	0.50	n/a	179.5	0.61	n/a	207.3	0.71	n/a
Total	**100%**	217.2			267.9			309.3		

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3. Calculate Water Pump Savings

	Water	
Baseline 2010	16.2	Calculated based on ENERGY STAR calculator
Baseline 2011	9.5	New Federal Standard WF
ENERGY STAR 2010	7.5	Energy Star minimum standard
ENERGY STAR 2011	6	New Energy Star minimum standard
CEE Tier 3	4.5	CEE Tier 3 Standard

	ENERGY STAR 2010	ENERGY STAR 2011	CEE TIER 3		
Annual Water Savings/load	28.1	11.3	16.2	Gal	Calculated based on ENERGY STAR calculator
Annual Gallons saved	7940	3193	4561	Gal	Calculated
Annual CCF	10.6	4.3	6.1	CCF	Calculated
Water Pump Savings	31.0	12.5	17.8	kWh	0.0039kWh Community/Municipal Water and Wastewate

4. Multiply savings by DHW and Dryer Fuel Mix

Residential Lighting Markdown Impact Evaluation (2009)

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)	0.81
Lifetime Install Rate (from 2009 RLW study)	0.97
Therefore 'future install'	0.16

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%

To reflect additional future savings from units replacing CFLs in future

Measure Life	5.7	yrs

To account for additional installs replacing incandescents - assume installed in first year.

Install Rate	0.88

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

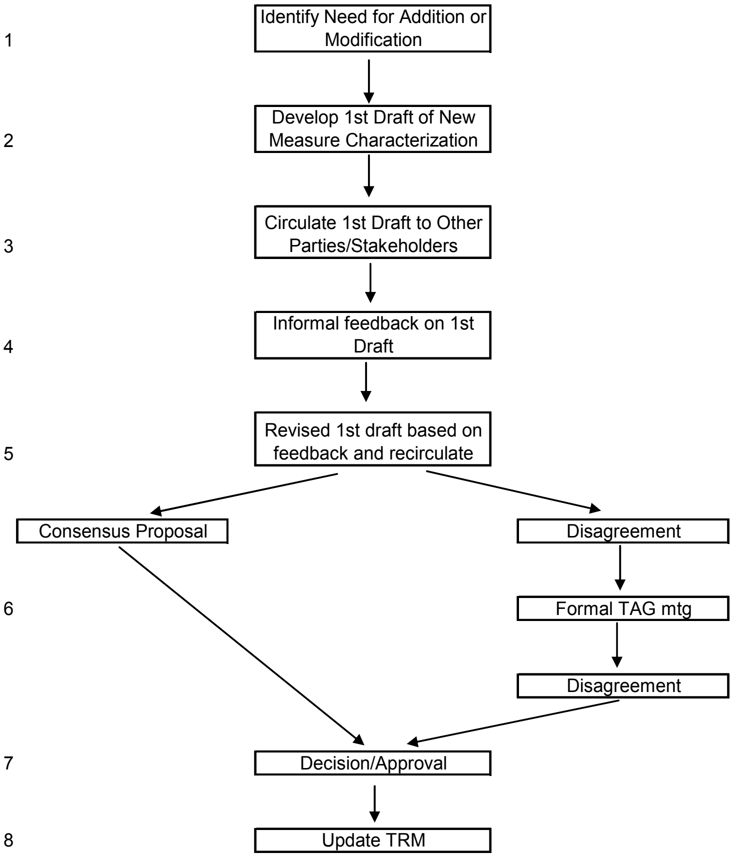
Once a TRM has been developed, it is vital that it is kept up to date, amended, and maintained in a timely and effective manner. There are three main points in time when a TRM is most likely to require changes:

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.

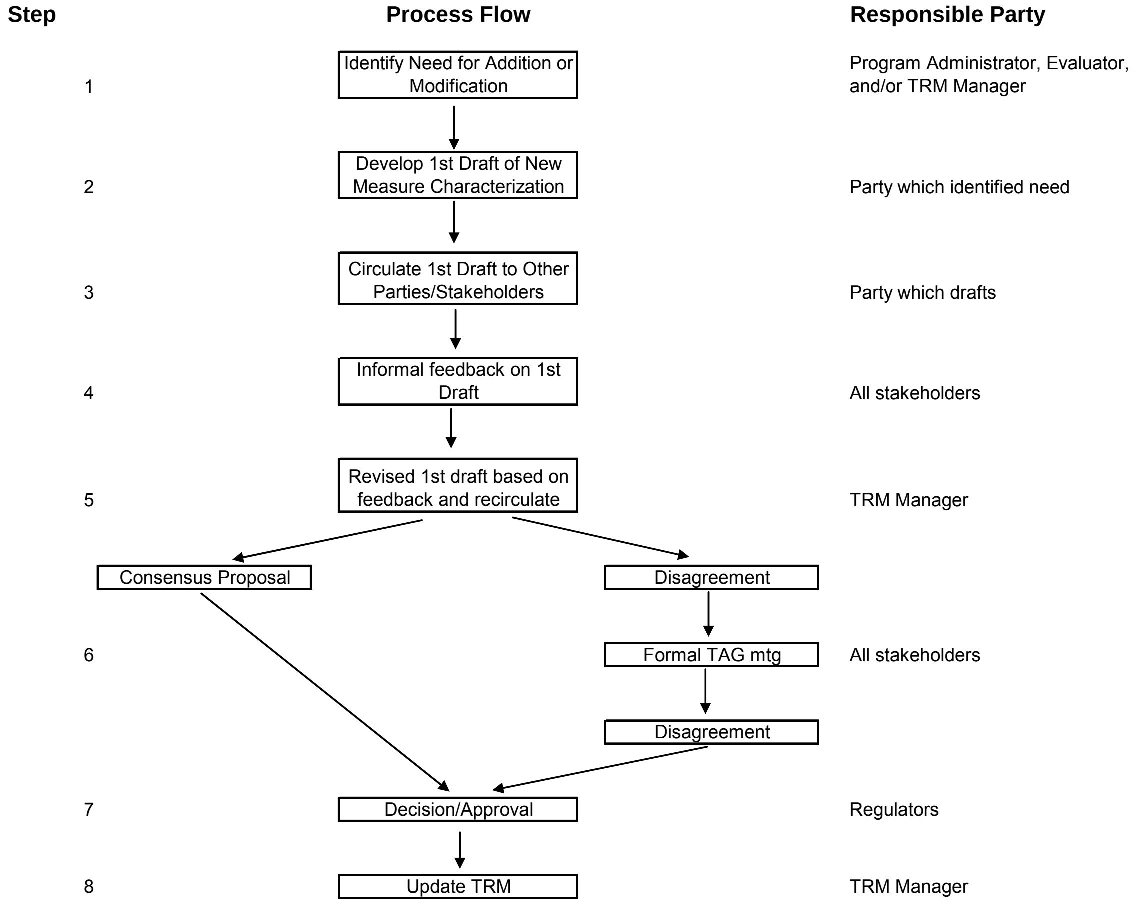
The flowchart presented below outlines steps that will result in effective review and quality control for TRM updates.

TRM Update Process Flow Chart



Step	Process Flow	Responsible Party
1	Identify Need for Addition or Modification	Program Administrator, Evaluator, and/or TRM Manager
2	Develop 1st Draft of New Measure Characterization	Party which identified need
3	Circulate 1st Draft to Other Parties/Stakeholders	Party which drafts
4	Informal feedback on 1st Draft	All stakeholders
5	Revised 1st draft based on feedback and recirculate	TRM Manager
	Consensus Proposal Disagreement	
6	Formal TAG mtg	All stakeholders
	Disagreement	
7	Decision/Approval	Regulators
8	Update TRM	TRM Manager

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_TRMversionv#.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**