TRM | MID-ATLANTIC
TECHNICAL REFERENCE MANUAL

# MARYLAND/MID-ATLANTIC TECHNICAL REFERENCE MANUAL

## VERSION 10

**Final**
**May 2019**

EVALUATION, MEASUREMENT
& VERIFICATION

Northeast Energy Efficiency Partnerships

# MARYLAND/MID-ATLANTIC
# TECHNICAL REFERENCE MANUAL
## VERSION 10

March 2020

**Prepared by Shelter Analytics**

**Facilitated and Managed by Northeast Energy Efficiency Partnerships**

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*All measure assumptions are locked down in Maryland three years from June 1, 2020 through May 31, 2023 EXCEPT residential and commercial Smart Thermostat measures and full load heating hours for commercial boilers; these measures/assumptions are locked down for one year, June 1, 2020 through May 31, 2021.

## Acknowledgements

This report reflects the invaluable contributions of multiple individuals.

We would like to recognize the report’s lead authors. This update of the Maryland/Mid-Atlantic Technical Reference Manual (TRM) was prepared by Shelter Analytics/Longtrail Sustainability. Bret Hamilton, project manager, was assisted by Keith Downes, Guidehouse Consulting, Glenn Reed, Energy Futures Group, and Paul Scheckel, Parsec Energy. Elizabeth Titus, Senior Advisor, served a key role in the development of the report. Formatting and edits were provided by Lisa Cascio, Director of Partner Engagement, Victoria Salvatore, Marketing Associate, and Andrew Winslow, NEEP intern.

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Finally, as this is an update to a previous report, NEEP would like to take this opportunity to reiterate acknowledgement of the original authors and contributors of previous versions of this report, which continue to serve as the foundation upon which this update is based.

## About NEEP

Founded in 1996, NEEP is a non-profit whose goal is to assist the Northeast and Mid-Atlantic region to reduce building sector energy consumption three percent per year and carbon emissions 40 percent by 2030 (relative to 2001). Our mission is to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities. We do this by fostering collaboration and innovation, developing tools, and disseminating knowledge to drive market transformation. We envision the region's homes, buildings, and communities transformed into efficient, affordable, low-carbon, resilient places to live, work, and play. To learn more about NEEP, visit our website at http://www.neep.org.

Disclaimer: NEEP verified the data used for this document paper to the best of our ability. The contents of this document 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. It does not necessarily reflect the opinion and judgments of all NEEP Board members, NEEP Sponsors, or project participants and funders. 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.

## About Shelter Analytics/Long Trail Sustainability

**Shelter Analytics, LLC** is dedicated to promoting energy efficiency through planning and integrated design concepts in programs, buildings and businesses. We combine our experience and integrity with innovative approaches to support and improve best-practice methods from planning through implementation. In 2019 we merged with Long Trail Sustainability.

## Introduction

The Mid-Atlantic Technical Reference Manual (TRM) is a technical assistance project that originated in the Regional Evaluation, Measurement and Verification Forum (EM&V Forum) and has been supported by Maryland, Delaware, and District of Columbia stakeholders. The EM&V Forum existed from 2009 through 2017; it was facilitated by NEEP to support the transparency, role and credibility of energy efficiency and demand resource savings, costs and emission impacts in current and emerging energy and environmental policies and markets in the Northeast, New York, and the Mid-Atlantic region. Since 2017 NEEP continues its involvement in various regional EM&V activities, including facilitation of the annual updates to the Technical Reference Manual.

This intent of the Technical Reference Manual is to develop and document in detail common assumptions for significant prescriptive residential and commercial/industrial electric energy efficiency measures savings. Measures were chosen by consensus of the subcommittee and project team. For each measure, the TRM includes either specific deemed values or algorithms[1] for calculating:

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

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

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

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

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

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

## Approach

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

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

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

Development of the TRM consisted of the following tasks:

**Task 1: Prioritization/Measure Selection.**

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

Measures are selected on the basis of projected or expected savings from program data, by measure type expert judgment and review of other relevant criteria available from regulatory filings and the region’s Program Administrators.

**Task 2: Development of Parameters Used to Calculate Impacts.**

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

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

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

- **Credibility.** The savings estimates and any related estimates of the cost-effectiveness of efficiency investments are credible.
- **Accuracy and completeness.** The individual assumptions or calculation protocols are accurate, and measure characterizations capture the full range of effects on savings.
- **Transparency.** The assumptions are considered by a variety of stakeholders to be transparent – that is, widely known, widely accepted, and developed and refined through an open process that encourages and addresses challenges from a variety of stakeholders.
- **Cost efficiency.** The contents of the TRM addressed all inputs that were within the established project scope and constraints. Sponsors recognize that there are improvements and additions that can be made in future generations of this document.

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

**Task 3: Development of Recommendations for Update.**

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

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

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

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

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

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

**Task 4: Delivery of Draft and Final Product.**

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

## Use of the TRM

As noted above, the TRM is intended to serve as an important tool to support rate-funded efficiency investments; for planning, implementation and assessment of success in meeting specific state goals. In addition, the TRM is intended to support the bidding of efficiency resources into capacity markets, such as PJM's Reliability Pricing Model and in setting and tracking future environmental and climate change goals. It provides a common platform for the Mid-Atlantic stakeholders to characterize measures within their efficiency programs, analyze and meaningfully compare cost-effectiveness of measures and programs, communicate with policymakers about program details, and it can guide future evaluation and measurement activity and help identify priorities for investment in further study, needed either at a regional or individual organizational level.

The savings estimates are expected to serve as representative, recommended values, or ways to calculate savings based on program-specific information. All information is presented on a per measure basis. In using the measure-specific information in the TRM, it is helpful to keep the following notes in mind:

- Additional information about the program design is sometimes included in the measure description because program design can affect savings and other parameters.
- Savings algorithms are typically provided for each measure. For a number of measures, prescriptive values for each of the variables in the algorithm are provided along with the output from the algorithm. That output is the deemed savings. For other measures, prescriptive values are provided for only some of the variables in the algorithm, with the term "actual" or "actual installed" provided for the others. In those cases – which one might call "deemed calculations" rather than "deemed savings" – users of the TRM are expected to use actual efficiency program data (e.g. capacities or rated efficiencies of central air conditioners) in the formula to compute savings. Note that the TRM typically provides *example calculations* for measures requiring "actual" values. These are for illustrative purposes only.
- All estimates of savings are annual savings and are assumed to be realized for each year of the measure life (unless otherwise noted).

- Unless otherwise noted, measure life is defined to be "the life of an energy consuming measure, including its equipment life and measure persistence (not savings persistence)" (EMV Forum Glossary). Conceptually it is similar to expected useful life, but the results are not necessarily derived from modeling studies, and many are from a report completed for New England program administrators' and regulators' State Program Working Group that is currently used to support the New England Forward Capacity Market M&V plans.
- Where deemed values for savings are provided, these represent average savings that could be expected from the average measures that might be installed in the region during the current program year.
- For measures that are not weather-sensitive, peak savings are estimated whenever possible as the average of savings between 2 pm and 6 pm across all summer weekdays (i.e. PJM's EE Performance Hours for its Reliability Pricing Model). Where possible for cooling measures, we provide estimates of peak savings in two different ways. The primary way is to estimate peak savings during the most typical peak hour (assumed here to be 5 p.m.) on days during which system peak demand typically occurs (i.e., the hottest summer weekdays). This is most indicative of actual peak benefits. The secondary way – typically provided in a footnote – is to estimate peak savings as it is measured for non-cooling measures: the average between 2 pm and 6 pm across *all* summer weekdays (regardless of temperature). The second way is presented so that values can be bid into the PJM RPM.
- Wherever possible, savings estimates and assumptions are based on mid-Atlantic data. However, a number of assumptions – including assumptions regarding peak coincidence factors – are based on sources from other regions, often adjusted for climate or other known regional differences.
- While this information is not perfectly transferable, due to differences in definitions of peak periods as well as geography, climate and customer mix, it was used because it was the most transferable and usable source available at the time.[2]
- Users will note that the TRM presents engineering equations for most measures. These were judged to be desirable because they convey information clearly and transparently, and they are widely accepted in the industry. Unlike simulation model results, they also provide flexibility and opportunity for users to substitute locally specific information and to update some or all parameters as they become available on an ad hoc basis. One limitation is that certain interactive effects between end uses, such as how reductions in waste heat from many efficiency measures impacts space conditioning, are not universally captured in this version of the TRM.[3]
- For some of the whole-building program designs that are being planned or implemented in the Mid-Atlantic, simulation modeling may be needed to estimate savings.
- In general, the baselines included in the TRM are intended to represent average conditions in the Mid-Atlantic. Some are based on data from the Mid-Atlantic, such as household consumption characteristics provided by the Energy Information

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

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

Administration. Some are extrapolated from other areas, when Mid-Atlantic data are not available. Some are based on code.

- The TRM anticipates the effects of changes in efficiency standards for measures as appropriate, specifically lighting and motors.

The following table outlines the terms used to describe the assumed baseline conditions for each measure. The third portion of each measure code for each measure described in this TRM includes the abbreviation of the program type for which the characterization is intended:

| Baseline Condition | Attributes |
|---|---|
| Time of Sale (TOS) | Definition: A program in which the customer is incented to purchase or install higher efficiency equipment than if the program had not existed. This may include retail rebate (coupon) programs, upstream buydown programs, online store programs, contractor based programs, or CFL giveaways as examples. May include replacement or existing equipment at the end of it's life (i.e., replace on burnout), or purchase of new equipment. In cases where a new contruction characterization isn't explicitly provided, the TOS characterization is typically appropriate.<br>Baseline = New standard efficiency or code compliant equipment.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Appliance rebate |
| New Construction (NC) | Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices.<br>Baseline = Building code or federal standards.<br>Efficient Case = The program's level of building specification<br>Example: Building shell and mechanical measures |
| Retrofit (RF) | Definition: A program that *upgrades* or enhances existing equipment.<br>Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life.<br>Efficient Case = Post-retrofit efficiency of equipment.<br>Example: Air sealing, insulation, and controls. |
| Early Replacement (EREP) | Definition: A program that *replaces* existing, operational equipment.[4]<br>Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the remaining life of the existing equipment is over.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Refrigerators and freezers. |
| Early Retirement (ERET) | Definition: A program that *retires* inefficient, operational duplicative equipment or inefficient equipment that might otherwise be resold.<br>Baseline = The existing equipment, which is retired and not replaced.<br>Efficient Case = Assumes zero consumption since the unit is retired.<br>Example: Appliance recycling. |

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

| Baseline Condition | Attributes |
|---|---|
| Direct Install (DI) | Definition: A program where measures are installed during a site visit.<br>Baseline = Existing equipment.<br>Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice.<br>Example: Lighting and low-flow hot water measures |

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

## Measure Cost Development and Use

Measure costs are calculated differently depending upon the program type, discussed above, used to promote a given measure. These calculations are summarized below. All incremental costs and operation & maintenance savings are maintained in Appendix G.

### Time of Sale and New Construction Incremental Costs

Calculations of Time of Sale and New Construction incremental costs in the Mid-Atlantic TRM are generally the difference between the measure equipment and labor costs and the baseline equipment and labor costs. In most cases, the measure and baseline labor costs are equal and so the time of sale incremental cost is simply the difference between the baseline and measure equipment costs. In general, no discounting of future costs is needed since all costs are incurred at the time of project installation.

### Retrofit and Full Costs

Retrofit measure incremental costs and full costs are equal to the total measure costs. Generally, no discounting of future costs is needed since all costs are incurred at the time of project installation. Retrofit measures generally comprise efficiency enhancement such as building shell measures, HVAC tune ups, etc.  Full cost values may be needed to estimate program costs for programs that pay all or a percentage of project costs.

### Early Replacement Incremental Costs

Calculation of early replacement incremental costs in the Mid-Atlantic TRM includes two components:

1. The discounted future costs that would have been incurred when the replaced equipment would have needed to be replaced had it not been replaced early needs to be subtracted from the initial measure costs; and
2. The present value costs associated with purchasing the high efficiency equipment today while the existing equipment is still operational.

The methods and rationale are discussed in Evergreen Economics, Michals Energy and Phil Wilhems, Early Replacement Measures Study Final Phase II Research Report, November 4, 2015 for the Evaluation, Measurement and Verification Forum facilitated by Northeast Energy

Efficiency Partnerships, pp. 36-45. See http://www.neep.org/sites/default/files/resources/FINAL%20NEEP%20Report.pdf.

## Measure lockdown in Maryland

All measure assumptions in the v10 Maryland/Mid-Atlantic TRM are locked down for three years from June 1, 2020 through May 31, 2023 EXCEPT residential and commercial Smart Thermostat measures and full load heating hours for commercial boilers; these measures/assumptions are locked down for one year, June 1, 2020 through May 31, 2021.

## TRM Update History

| Version | Issued |
|---|---|
| 1.1 | October 2010 |
| 1.2 | March 2011 |
| 2.0 | July 2011 |
| 3.0 | January 2013 |
| 4.0 | June 2014 |
| 5.0 | June 2015 |
| 6.0 | May 2016 |
| 7.0 | May 2017 |
| 7.5 | October 2017 |
| 8.0 | May 2018 |
| 9.0 | May 2019 |
| 10.0 | May 2020 |

# RESIDENTIAL MARKET SECTOR

*Lighting End Use*

# Solid State Lighting (LED) Recessed Downlight Luminaire

**Unique Measure Code: RS_LT_TOS_SSLDWN_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight luminaire in place of an incandescent downlight lamp (i.e. time of sale). The SSL downlight should meet the ENERGY STAR Luminaires Version 2.2 specification[5]. The characterization of this measure should not be applied to other types of LEDs.

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

The measure provides assumptions for bulbs purchased or distributed through residential energy-efficiency programs. To account for different end-uses through the various distribution channels, assumptions are provided for Residential, Commercial, and Multi-Family).

### Definition of Baseline Condition

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

### Definition of Efficient Condition

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

### Assumptions Regarding Combined Residential and Commercial Savings

For this measures savings are to be calculated assuming that that 7% of the program measures are installed in commercial facilities and 93% are installed in residential homes. To estimate savings:

1) Apply residential inputs to all lighting measures and generate residential savings.
2) Apply commercial inputs to all measures and generate commercial savings.

Utility-specific residential and commercial input values are provided in the tables below.

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[5] ENERGY STAR specification can be viewed here: https://www.energystar.gov/sites/default/files/Luminaires%20V2.2%20Final%20Specification.pdf

### Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) /1{,}000) * ISR * HOURS * WHFs$$

*Where:*

*WattsBase = Connected load of baseline lamp*

*= Actual if retrofit, if LED lumens is known – find the equivalent baseline wattage from the table below[6], if unknown assume 65W [7]*

| Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|
| 400 | 449 | 40 |
| 450 | 499 | 45 |
| 500 | 649 | 50 |
| 650 | 1419 | 65 |

*WattsEE = Connected load of efficient lamp*

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

*ISR* Two ISRs are presented below:

- Storage ISRs – These use a net present value approach to account for lamps installed in subsequent program years, which is an UMP-approved method for determining storage lamp savings. Storage ISRs should be used for Utility Energy and Demand Savings.
- First Year ISRs – These values should be used to calculate all PJM savings.

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – BGE**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.959 | 1.03 |
| WHFd | 1.241 | 1.25 |
| Summer PJM WHF | 1.227 | 1.27 |
| Winter PJM WHF | 0.815 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |

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

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

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

| | | |
|---|---|---|
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – Pepco**

| Parameter Value | Evaluation-Recommended ***Residential*** Values | Evaluation-Recommended ***Commercial*** Values |
|---|---|---|
| WHFe | 0.947 | 1.03 |
| WHFd | 1.264 | 1.25 |
| Summer PJM WHF | 1.221 | 1.27 |
| Winter PJM WHF | 0.789 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

### Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – Delmarva Power

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.915 | 1.03 |
| WHFd | 1.245 | 1.25 |
| Summer PJM WHF | 1.211 | 1.27 |
| Winter PJM WHF | 0.689 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – PE**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.956 | 1.03 |
| WHFd | 1.266 | 1.25 |
| Summer PJM WHF | 1.251 | 1.27 |
| Winter PJM WHF | 0.818 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – SMECO**

| Parameter Value | Evaluation-Recommended Residential Values | Evaluation-Recommended Commercial Values |
|---|---|---|
| WHFe | 0.963 | 1.03 |
| WHFd | 1.241 | 1.25 |
| Summer PJM WHF | 1.215 | 1.27 |
| Winter PJM WHF | 0.751 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

### Summer Coincident Peak kW Savings Algorithm

Use the appropriate waste heat factors (WHFs), ISRs, and coincident factors (CFs) from the tables above depending on whether utility or PJM demand savings are to be calculated.

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

*Where:*

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

*CF* = *Summer Peak Coincidence Factor for measure*
See tables above

Illustrative example for BGE Residential demand savings component – do not use as default assumption

$$\Delta kW_{PJM} = ((65 - 9.2) / 1{,}000) * 0.965 * 1.241 * 0.059$$

$$= 0.0039 \text{ kW}$$

### Annual Fossil Fuel Savings Algorithm

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

$$\Delta MMBtuPenalty^{9} = - ((((WattsBase - WattsEE) / 1000) * ISR * Hours * HF * 0.003412) / \eta Heat) * \%FossilHeat$$

*Where:*

*HF* = *Heating Factor or percentage of light savings that must be heated*
= *47%*[10] *for interior or unknown location*
= *0% for exterior or unheated location*

*0.003412* =*Converts kWh to MMBtu*

*ηHeat* = *Efficiency of heating system*
=*80%*[11]

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

---

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

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

[11] Minimum federal standard for residential furnaces.

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |
| Unknown | 62.5%[12] |

Illustrative example – do not use as default assumption

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

ΔMMBtuPenalty = - (((65 – 9.2)/1000) * 0.965 * 679 * 0.47 * 0.003412/0.75) * 1.0

= - 0.08 MMBtu

If home heating fuel is unknown:

ΔMMBtuPenalty = - (((65 - 9.2)/1000) * 0.965 * 679 * 0.47 * 0.003412/0.80) * 0.625

= - 0.046 MMBtu

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 20 years for Residential and Multi Family in-unit, and 8.4 years for Multi Family common areas for downlights featuring inseparable components, and 4.2 years for downlights with replaceable parts.[13]

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[12] Based on KEMA baseline study for Maryland.

[13] The ENERGY STAR Spec for SSL Recessed Downlights requires luminaires to maintain >=70% initial light output for 25,000 hours in an indoor application for separable luminaires and 50,000 for inseparable luminaires. Measure life is capped at 20 years.

# ENERGY STAR Integrated Screw Based SSL (LED) Lamp

**Unique Measure Code: RS_LT_TOS_SSLDWN_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp in place of an incandescent lamp.

The measure provides assumptions for two markets (Residential and Commercial).

### Definition of Baseline Condition

For time of sale replacement, the baseline wattage is assumed to be an incandescent or EISA compliant (where applicable) bulb installed in a screw-base socket[14]. Note that the baseline will be EISA compliant bulbs for all categories to which EISA applies. If the in situ lamp wattage is known and lower than the EISA mandated maximum wattage (where applicable), the baseline wattage should be assumed equal to the in situ lamp wattage.

### Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. The ENERGY STAR V2.1 specifications can be viewed here: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf

### Assumptions Regarding Combined Residential and Commercial Savings

For this measures savings are to be calculated assuming that that 7% of the program measures are installed in commercial facilities and 93% are installed in residential homes. To estimate savings:

3) Apply residential inputs to all lighting measures and generate residential savings.
4) Apply commercial inputs to all measures and generate commercial savings.

Utility-specific residential and commercial input values are provided in the tables below.

Use 93% of the residential savings and 7% of the commercial savings to generate total weighted Residential savings.[15]

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

[15] Results from future evaluation research may alter the percentage of lamps being installed in commercial applications. These results would be applied prospectively.

**Annual Energy Savings Algorithm**

ΔkWh = ((WattsBase - WattsEE) /1000) * ISR * HOURS * WHFe

*Where:*

*WattsBase* = *Based on lumens of the LED – find the ewquivalent baseline wattage from the table below.*

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|---|
| **Standard A-Type (medium-base)** | 250 | 449 | 25 |
| | 450 | 799 | 29 |
| | 800 | 1099 | 43 |
| | 1100 | 1599 | 53 |
| | 1600 | 1999 | 72 |
| | 2000 | 2599 | 72 |
| | 2600 | 3000 | 150 |
| | 3001 | 3999 | 200 |
| | 4000 | 6000 | 300 |
| **Decorative (medium-base, > 499 lumens)** | 500 | 1050 | 43 |
| **Globe (medium-base, > 499 lumens)** | 500 | 574 | 43 |
| | 575 | 649 | 53 |
| | 650 | 1099 | 72 |
| | 1100 | 1300 | 150 |
| **3-Way, bug, marine, rough service, infrared** | 250 | 449 | 25 |
| | 450 | 799 | 40 |
| | 800 | 1099 | 60 |
| | 1100 | 1599 | 75 |
| | 1600 | 1999 | 100 |
| | 2000 | 2549 | 125 |
| | 2550 | 2999 | 150 |
| **Globe**<br>(any base, < 500 lumens)[1] | 90 | 179 | 10 |
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |

| | | | |
|---|---|---|---|
| | 350 | 499 | 40 |
| **Globe (candelabra or intermediate base, ≥ 500 lumens)** | 500 | 574 | 60 |
| | 575 | 649 | 75 |
| | 650 | 1099 | 100 |
| | 1100 | 1300 | 150 |
| **Decorative**<br>(Shapes B, BA, C, CA, DC, F, G, any base, < 500 lumens)[2] | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 500 | 40 |
| **Decorative (candelabra or intermediate base, ≥ 500 lumens)** | 500 | 1050 | 60 |
| **Reflector with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1199 | 65 |
| **R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)** | 640 | 739 | 40 |
| | 740 | 849 | 45 |
| | 850 | 1179 | 50 |
| | 1180 | 1419 | 65 |
| | 1420 | 1789 | 75 |
| | 1790 | 2049 | 90 |
| | 2050 | 2579 | 100 |
| | 2580 | 3429 | 120 |
| | 3430 | 4270 | 150 |
| **R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26'' and ≤ 2.5" (*see exceptions below)** | 540 | 629 | 40 |
| | 630 | 719 | 45 |
| | 720 | 999 | 50 |
| | 1000 | 1199 | 65 |
| | 1200 | 1519 | 75 |
| | 1520 | 1729 | 90 |
| | 1730 | 2189 | 100 |
| | 2190 | 2899 | 120 |
| | 2900 | 3850 | 150 |
| ***ER30, BR30, BR40, or ER40** | 400 | 449 | 40 |

| | | | |
|---|---|---|---|
| | 450 | 499 | 45 |
| | 500 | 649-1179[3] | 50 |
| ***BR30, BR40, or ER40** | 650 | 1419 | 65 |
| ***R20** | 400 | 449 | 40 |
| | 450 | 719 | 45 |
| ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 20 |
| | 300 | 399-639[4] | 30 |

For PAR, MR, and MRX lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The approach is specified in detail on page 366 of version 6.0 of the Illinois TRM.[16] The formula to determine baseline wattage is based on the ENERGY STAR Center Beam Candle Power tool.[17] If CBCP and beam angle information are not available, or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.

*WattsEE* = *Actual LED wattage*

*ISR* Two ISRs are presented below:

- Storage ISRs – These use a net present value approach to account for lamps installed in subsequent program years, which is a UMP-approved method for determining storage lamp savings. Storage ISRs should be used for Utility Energy and Demand Savings.
- First Year ISRs – These values should be used to calculate all PJM savings.

*HOURS* = *Average hours of use per year*
See utility-specific Parameter Valuetables below

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[16] http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf

[17] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – BGE**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.959 | 1.03 |
| WHFd | 1.241 | 1.25 |
| Summer PJM WHF | 1.227 | 1.27 |
| Winter PJM WHF | 0.815 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – Pepco**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.947 | 1.03 |
| WHFd | 1.264 | 1.25 |
| Summer PJM WHF | 1.221 | 1.27 |
| Winter PJM WHF | 0.789 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |

| | | |
|---|---|---|
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – Delmarva Power**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.915 | 1.03 |
| WHFd | 1.245 | 1.25 |
| Summer PJM WHF | 1.211 | 1.27 |
| Winter PJM WHF | 0.689 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – PE**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.956 | 1.03 |
| WHFd | 1.266 | 1.25 |
| Summer PJM WHF | 1.251 | 1.27 |
| Winter PJM WHF | 0.818 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |

| | | |
|---|---|---|
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – SMECO**

| Parameter Value | Evaluation-Recommended *Residential* Values | Evaluation-Recommended *Commercial* Values |
|---|---|---|
| WHFe | 0.963 | 1.03 |
| WHFd | 1.241 | 1.25 |
| Summer PJM WHF | 1.215 | 1.27 |
| Winter PJM WHF | 0.751 | 0.82 |
| Storage ISR (LED) | 0.965 | 1.00 |
| First Year ISR (LED) | 0.86 | 1.00 |
| First Year ISR (Fixture) | 1.00 | 1.00 |
| HOU | 1.86 | 12.27 |
| Utility CF | 0.059 | 0.70 |
| Summer PJM CF | 0.058 | 0.70 |
| Winter PJM CF | 0.124 | 0.45 |
| Percent of Installations | 93% | 7% |

*Source:* Cadmus and Navigant analyses

Illustrative example – do not use as default assumption

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

$$\Delta kWh = ((50 - 10)/ 1,000) * 0.965 * 679 * 0.959$$

$$= 25.1 \text{ kWh}$$

### Summer Coincident Peak kW Savings Algorithm

Use the appropriate waste heat factors (WHFs), ISRs, and coincident factors (CFs) from the tables above depending on whether utility or PJM demand savings are to be calculated.

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

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

*CF* = *Summer Peak Coincidence Factor for measure*
See tables above

Illustrative example – do not use as default assumption

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

$$\Delta kW_{PJM} = ((50 – 10)/ 1,000) * 0.965 * 1.17 * 0.084$$

$$= 0.0028 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

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

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

*Where:*

*HF* = *Heating Factor or percentage of light savings that must be heated*
= *47%*[18] *for interior or unknown location*
= *0% for exterior or unheated location*

*0.003412* =*Converts kWh to MMBtu*

*ηHeat* = *Efficiency of heating system*
=*80%*[19]

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

---

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

[19] Minimum federal standard for residential furnaces.

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |
| Unknown | 62.5%[20] |

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" is installed in a residential interior location in the BGE service territory with unknown heating fuel.

ΔMMBtuPenalty = - ((50 - 10)/ 1,000) * 0..965 * 679 * 0.47 * 0.003412/0.80) * 0.625

= - 0.033 MMBtu

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The tables below show the assumed measure life for ENERGY STAR Version 2.1.

| | Measure Life, Energy Star V2.0 | | | | |
|---|---|---|---|---|---|
| | Rated Life[21] | Residential interior, in-unit Multi Family or unknown | | Exterior | Unknown |
| **Omnidirectional** | 15,000 | 16.3 | | 9.1 | 13.6 |
| **Decorative** | 15,000 | 16.3 | | 9.1 | 13.6 |
| **Directional** | 15,000 | 16.3 | | 9.1 | 13.6 |

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[20] Based on KEMA baseline study for Maryland.

[21] The ENERGY STAR Spec v2.1 for Integrated Screw Based SSL bulbs requires lamps to maintain >=70% initial light output for 15,000 hrs. Lifetime capped at 20 years.

# ENERGY STAR Integrated Screw Based SSL (LED) Lamp Direct Install

**Unique Measure Code: RS_LT_DI_SSLDWN_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes savings from the direct installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp in place of an incandescent.

### Definition of Baseline Condition

For direct install of LED lamps, the baseline wattage is assumed to be the replaced (in situ) lamp's wattage when in situ lamp information is adequately[22] documented. If a utility chooses to not collect in situ documentation for any lamps, assume the baseline wattages to be the current lumen-based code minimum.

### Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. The ENERGY STAR V2.1 specifications can be viewed here: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf

### Annual Energy Savings Algorithm

ΔkWh = ((WattsBase - WattsEE) /1000) * ISR * HOU*365 * WHFe

*Where:*

*WattsBase* =
*= Actual if documented.*
*If unknown, based on lumens of the replaced bulb – find the equivalent baseline wattage from the table below.*

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase | | |
|---|---|---|---|---|---|
| **Standard A-Type (medium-base)** | 250 | 449 | 25 | | |
| | 450 | 799 | 29 | | |
| | 800 | 1099 | 43 | | |
| | 1100 | 1599 | 53 | | |

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[22] Adequate documentation to be determined by jurisdiction.

| | | | | | |
|---|---|---|---|---|---|
| | 1600 | 1999 | 72 | | |
| | 2000 | 2599 | 72 | | |
| | 2600 | 3000 | 150 | | |
| | 3001 | 3999 | 200 | | |
| | 4000 | 6000 | 300 | | |
| **Decorative (medium-base, > 499 lumens)** | 500 | 1050 | 43 | | |
| **Globe (medium-base, > 499 lumens)** | 500 | 574 | 43 | | |
| | 575 | 649 | 53 | | |
| | 650 | 1099 | 72 | | |
| | 1100 | 1300 | 150 | | |
| **3-Way, bug, marine, rough service, infrared** | 250 | 449 | 25 | | |
| | 450 | 799 | 40 | | |
| | 800 | 1099 | 60 | | |
| | 1100 | 1599 | 75 | | |
| | 1600 | 1999 | 100 | | |
| | 2000 | 2549 | 125 | | |
| | 2550 | 2999 | 150 | | |
| **Globe**<br>(any base, < 500 lumens)[1] | 90 | 179 | 10 | | |
| | 180 | 249 | 15 | | |
| | 250 | 349 | 25 | | |
| | 350 | 499 | 40 | | |
| **Globe (candelabra or intermediate base, ≥ 500 lumens)** | 500 | 574 | 60 | | |
| | 575 | 649 | 75 | | |
| | 650 | 1099 | 100 | | |
| | 1100 | 1300 | 150 | | |
| **Decorative**<br>(Shapes B, BA, C, CA, DC, F, G, any base, < 500 lumens)[2] | 70 | 89 | 10 | | |
| | 90 | 149 | 15 | | |
| | 150 | 299 | 25 | | |
| | 300 | 500 | 40 | | |

| | | | | | |
|---|---|---|---|---|---|
| **Decorative (candelabra or intermediate base, ≥ 500 lumens)** | 500 | 1050 | 60 | | |
| **Reflector with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 40 | | |
| | 450 | 499 | 45 | | |
| | 500 | 649 | 50 | | |
| | 650 | 1199 | 65 | | |
| **R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)** | 640 | 739 | 40 | | |
| | 740 | 849 | 45 | | |
| | 850 | 1179 | 50 | | |
| | 1180 | 1419 | 65 | | |
| | 1420 | 1789 | 75 | | |
| | 1790 | 2049 | 90 | | |
| | 2050 | 2579 | 100 | | |
| | 2580 | 3429 | 120 | | |
| | 3430 | 4270 | 150 | | |
| **R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26'' and ≤ 2.5" (*see exceptions below)** | 540 | 629 | 40 | | |
| | 630 | 719 | 45 | | |
| | 720 | 999 | 50 | | |
| | 1000 | 1199 | 65 | | |
| | 1200 | 1519 | 75 | | |
| | 1520 | 1729 | 90 | | |
| | 1730 | 2189 | 100 | | |
| | 2190 | 2899 | 120 | | |
| | 2900 | 3850 | 150 | | |
| ***ER30, BR30, BR40, or ER40** | 400 | 449 | 40 | | |
| | 450 | 499 | 45 | | |
| | 500 | 649-1179[3] | 50 | | |
| ***BR30, BR40, or ER40** | 650 | 1419 | 65 | | |
| ***R20** | 400 | 449 | 40 | | |
| | 450 | 719 | 45 | | |
| ***All reflector lamps** | 200 | 299 | 20 | | |

| | | | | | |
|---|---|---|---|---|---|
| **below lumen ranges specified above** | 300 | 399-639[4] | 30 | | |

For PAR, MR, and MRX lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The approach is specified in detail on page 366 of version 6.0 of the Illinois TRM.[23] The formula to determine baseline wattage is based on the ENERGY STAR Center Beam Candle Power tool.[24] If CBCP and beam angle information are not available, or if the equation below returns a negative value (or undefined), use the manufacturer's recommended baseline wattage equivalent.

*WattsEE* = *Actual LED wattage*

*ISR* Three ISRs are presented below:

*HOURS* = *Average hours of use per year*
See utility-specific Parameter Value tables below

**Parameter Values Recommended to Calculate Energy and Demand Savings for Residential Direct Install Lighting Measures – BGE**

| Parameter Value | Evaluation-Recommended QHEC - SF Values | Evaluation-Recommended QHEC - MF Values | Evaluation-Recommended HPwES Values |
|---|---|---|---|
| WHFe | 0.959 | 0.959 | 0.959 |
| WHFd | 1.241 | 1.241 | 1.241 |
| Summer PJM WHF | 1.227 | 1.227 | 1.227 |
| Winter PJM WHF | 0.815 | 0.815 | 0.815 |
| ISR | 0.97 | 0.82 | 0.95 |
| HOU (LED) | 1.86 | 3.02 | 1.86 |
| CF (LED) | 0.059 | 0.111 | 0.059 |
| Summer PJM CF (LED) | 0.058 | 0.058 | 0.058 |
| Winter PJM CF | 0.124 | 0.124 | 0.124 |

*Source:* Cadmus analysis

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[23] http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Version_6.0_dated_February_8_2017_Final_Volumes_1-4_Compiled.pdf

[24] http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

**Parameter Values Recommended to Calculate Energy and Demand Savings for Residential Direct Install Lighting Measures – Pepco**

| Parameter Value | Evaluation-Recommended QHEC - SF Values | Evaluation-Recommended QHEC - MF Values | Evaluation-Recommended HPwES Values |
|---|---|---|---|
| WHFe | 0.947 | 0.947 | 0.947 |
| WHFd | 1.264 | 1.264 | 1.264 |
| Summer PJM WHF | 1.221 | 1.221 | 1.221 |
| Winter PJM WHF | 0.789 | 0.789 | 0.789 |
| ISR | 0.97 | 0.82 | 0.95 |
| HOU (LED) | 1.86 | 3.02 | 1.86 |
| CF (LED) | 0.059 | 0.111 | 0.059 |
| Summer PJM CF (LED) | 0.058 | 0.058 | 0.058 |
| Winter PJM CF | 0.124 | 0.124 | 0.124 |

*Source:* Cadmus analysis

**Parameter Values Recommended to Calculate Energy and Demand Savings for Residential Direct Install Lighting Measures – Delmarva Power**

| Parameter Value | Evaluation-Recommended QHEC - SF Values | Evaluation-Recommended QHEC - MF Values | Evaluation-Recommended HPwES Values |
|---|---|---|---|
| WHFe | 0.915 | 0.915 | 0.915 |
| WHFd | 1.245 | 1.245 | 1.245 |
| Summer PJM WHF | 1.211 | 1.211 | 1.211 |
| Winter PJM WHF | 0.689 | 0.689 | 0.689 |
| ISR | 0.97 | 0.82 | 0.95 |
| HOU (LED) | 1.86 | 3.02 | 1.86 |
| CF (LED) | 0.059 | 0.111 | 0.059 |
| Summer PJM CF (LED) | 0.058 | 0.058 | 0.058 |
| Winter PJM CF | 0.124 | 0.124 | 0.124 |

*Source:* Cadmus analysis

**Parameter Values Recommended to Calculate Energy and Demand Savings for Residential Direct Install Lighting Measures – PE**

| Parameter Value | Evaluation-Recommended QHEC - SF Values | Evaluation-Recommended QHEC - MF Values | Evaluation-Recommended HPwES Values |
|---|---|---|---|
| WHFe | 0.956 | 0.956 | 0.956 |
| WHFd | 1.266 | 1.266 | 1.266 |
| Summer PJM WHF | 1.251 | 1.251 | 1.251 |
| Winter PJM WHF | 0.818 | 0.818 | 0.818 |
| ISR | 0.97 | 0.82 | 0.95 |
| HOU (LED) | 1.86 | 3.02 | 1.86 |
| CF (LED) | 0.059 | 0.111 | 0.059 |
| Summer PJM CF (LED) | 0.058 | 0.058 | 0.058 |
| Winter PJM CF | 0.124 | 0.124 | 0.124 |
| *Source:* Cadmus analysis | | | |

**Table 1. Parameter Values Recommended to Calculate Energy and Demand Savings for Residential Direct Install Lighting Measures – SMECO**

| Parameter Value | Evaluation-Recommended QHEC - SF Values | Evaluation-Recommended QHEC - MF Values | Evaluation-Recommended HPwES Values |
|---|---|---|---|
| WHFe | 0.963 | 0.963 | 0.963 |
| WHFd | 1.241 | 1.241 | 1.241 |
| Summer PJM WHF | 1.215 | 1.215 | 1.215 |
| Winter PJM WHF | 0.751 | 0.751 | 0.751 |
| ISR | 0.97 | 0.82 | 0.95 |
| HOU (LED) | 1.86 | 3.02 | 1.86 |
| CF (LED) | 0.059 | 0.111 | 0.059 |
| Summer PJM CF (LED) | 0.058 | 0.058 | 0.058 |
| Winter PJM CF | 0.124 | 0.124 | 0.124 |
| *Source:* Cadmus analysis | | | |

Illustrative example – do not use as default assumption

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

$$\Delta kWh = ((50 - 10)/ 1{,}000) * 0.87 * 679 * 0.959))$$

$$= 22.7 \text{ kWh}$$

**Summer Coincident Peak kW Savings Algorithm**

Use the appropriate waste heat factors (WHFs) and coincident factors (CFs) from the tables above depending on whether utility or PJM demand savings are to be calculated.

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

*Where:*

WHFd = *Waste Heat Factor for Demand to account for cooling savings from efficient lighting.*
See tables above

CF = *Summer Peak Coincidence Factor for measure*
See tables above

Illustrative example – do not use as default assumption

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

$$\Delta kW_{PJM} = ((50 – 10)/ 1{,}000) * 0.87 * 1.241 * 0.059$$

$$= 0.0025 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

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

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

*Where:*

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

*heated*
*= 47%[25] for interior or unknown location*
*= 0% for exterior or unheated location*

*0.003412 =Converts kWh to MMBtu*

*ηHeat = Efficiency of heating system*
*=80%[26]*

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

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

Illustrative example – do not use as default assumption

A 10W 550 lumen LED directional lamp with medium screw bases diameter <=2.25" is installed in a residential interior location in the BGE service territory with unknown heating fuel.

$$\Delta \text{MMBtuPenalty} = - ((50 - 10)/ 1{,}000) * 0.965 * 679 * 0.47 * 0.003412/0.80) * 0.625$$

$$= - 0.030 \text{ MMBtu}$$

**Annual Water Savings Algorithm**

n/a

**Measure Life**

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

| | Measure Life, Energy Star V2.0 | | | | |
|---|---|---|---|---|---|
| | Rated Life[28] | Residential interior, in-unit Multi Family or unknown | | Exterior | Unknown |
| Omnidirectional | 15,000 | 16.3 | | 9.1 | 13.6 |
| Decorative | 15,000 | 16.3 | | 9.1 | 13.6 |
| Directional | 15,000[29] | 16.3 | | 9.1 | 13.6 |

---

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

[26] Minimum federal standard for residential furnaces.

[27] Based on KEMA baseline study for Maryland.

[28] The ENERGY STAR Spec v2.0 for Integrated Screw Based SSL bulbs requires lamps to maintain >=70% initial light output fo 15,000 hrs. Lifetime capped at 20 years.

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

# Occupancy Sensor – Wall-Mounted

**Unique Measure Code(s): RS_LT_RF_OSWALL_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure defines the savings associated with installing a wall-mounted occupancy sensor that switches lights off after a brief delay when it does not detect occupancy.

### Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

### Definition of Efficient Condition

The efficient condition is lighting that is controlled with an occupancy sensor. It is assumed that the controlled load is a mix of efficient and inefficient lighting.

### Annual Energy Savings Algorithm

$$\Delta kWh = kWconnected * HOURS * SVGe * ISR * WHFe$$

*Where:*

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

| Number of lamps in space with control (A) | Average lamp wattage (B) | kWconnected (AxB) |
|---|---|---|
| 6.8[30] | 0.034[31] | 0.230 |

*HOURS = Average hours of use per day. If space type is known, then use average of efficient and inefficient hours of use below[32]:*

| Lamp Type | Average Hours of Efficient and Inefficient Lamps |
|---|---|
| Attic | 0.4 |
| Basement | 2.6 |

---

[30] Connecticut LED Lighting Study Report (R154). NMR Group, Inc. January 28, 2016. Average of number of sockets in dining room, living space, bedroom, bathroom, and kitchen spaces.

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

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

| | |
|---|---|
| Bathroom | 1.3 |
| Bedroom | 1.3 |
| Closet | 0.3 |
| Crawl Space | 1.1 |
| Dining Room | 1.6 |
| Exterior | 1.3 |
| Garage | 0.9 |
| Hall | 1.4 |
| Kitchen | 3.5 |
| Laundry | 1.4 |
| Living Room | 1.9 |
| Mechanical | 0.2 |
| Office | 3.2 |
| Other | 0.9 |

If space type is not knowm, then assume:

| Installation Location | Daily Hours | Annual Hours |
|---|---|---|
| Residential interior and in-unit Multi Family | 1.66[33] | 604[34] |
| Multi Family Common Areas | 16.3 | 5,950[35] |
| Unknown | 1.66[36] | 604[37] |

*SVGe* = *Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
*= 30%* [38]

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

---

[33] Based on Navigant Consulting, "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 13. This assumption is an average of the hours of use for efficient lamps (CFLs and LEDs at 679 hrs./yr.) and inefficient lamps (529 hrs./yr.).

[34] Based on Navigant Consulting, "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 13. This assumption is an average of the hours of use for efficient lamps (CFLs and LEDs at 679 hrs./yr.) and inefficient lamps (529 hrs./yr.).

[35] Multifamily common area lighting assumption is 16.3 hours per day (5950 hours per year) based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010. This estimate is consistent with the Common Area "Non-Area Specific" assumption (16.2 hours per day or 5913 annually) from the Cadmus Group Inc., "Massachusetts Multifamily Program Impact Analysis", July 2012, p 2-4. http://ma-eeac.org/wordpress/wp-content/uploads/Massachusetts-Multifamily-Program-Impact-Analysis-Report-Appendix.pdf

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

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

[38] Cadmus Group Inc., "Massachusetts Multifamily Program Impact Analysis", July 2012. Appendix A. 6-1. The study notes that this value is informed by commercial occupancy sensor applications. This value is cited in the Massachusetts 2016-2018 Plan Technical Reference Manual.

*= 1.00* [39]

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

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – BGE**

| Parameter Value | Evaluation-Recommended *Residential* Values |
|---|---|
| WHFe | 0.959 |
| WHFd | 1.241 |
| Summer PJM WHF | 1.227 |
| Winter PJM WHF | 0.815 |
| Utility CF | 0.059 |
| Summer PJM CF | 0.058 |
| Winter PJM CF | 0.124 |
| | |
| *Source:* Cadmus and Navigant analyses | |

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – Pepco**

| Parameter Value | Evaluation-Recommended *Residential* Values |
|---|---|
| WHFe | 0.947 |
| WHFd | 1.264 |
| Summer PJM WHF | 1.221 |
| Winter PJM WHF | 0.789 |
| | |
| Utility CF | 0.059 |
| Summer PJM CF | 0.058 |
| Winter PJM CF | 0.124 |
| *Source:* Cadmus and Navigant analyses | |

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[39] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – Delmarva Power**

| Parameter Value | Evaluation-Recommended *Residential* Values |
|---|---|
| WHFe | 0.915 |
| WHFd | 1.245 |
| Summer PJM WHF | 1.211 |
| Winter PJM WHF | 0.689 |
| | |
| Utility CF | 0.059 |
| Summer PJM CF | 0.058 |
| Winter PJM CF | 0.124 |
| | |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – PE**

| Parameter Value | Evaluation-Recommended *Residential* Values |
|---|---|
| WHFe | 0.956 |
| WHFd | 1.266 |
| Summer PJM WHF | 1.251 |
| Winter PJM WHF | 0.818 |
| | |
| Utility CF | 0.059 |
| Summer PJM CF | 0.058 |
| Winter PJM CF | 0.124 |
| | |

*Source:* Cadmus and Navigant analyses

**Parameter Values Used to Calculate Energy and Demand Savings for Lighting Measures and Evaluation Recommended Values – SMECO**

| Parameter Value | Evaluation-Recommended *Residential* Values |
|---|---|
| WHFe | 0.963 |
| WHFd | 1.241 |
| Summer PJM WHF | 1.215 |
| Winter PJM WHF | 0.751 |
| | |
| Utility CF | 0.059 |
| Summer PJM CF | 0.058 |
| Winter PJM CF | 0.124 |
| | |
| *Source:* Cadmus and Navigant analyses | |

### Summer Coincident Peak kW Savings Algorithm

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

*Where:*

*SVGd* = *Percentage of lighting demand saved by lighting control; determined on a site-specific basis or using default below.*
= *30%*[40]

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

*CF* = *Summer Peak Coincidence Factor for measure*
See tables above

### Annual Fossil Fuel Savings Algorithm

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

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

---

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

*Where:*

*HF* = *Heating Factor or percentage of light savings that must be heated*
= *47%*[41] *for interior or unknown location*
= *0% for exterior or unheated location*

*0.003412* =*Converts kWh to MMBTU*

*ηHeat* = *Efficiency of heating system*
=*80%*[42]

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

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |
| Unknown | 62.5%[43] |

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 10 years.[44]

---

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

[42] Minimum federal standard for residential furnaces.

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

[44] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

# Connected Lighting

**Unique Measure Code(s): RS_LT_RF_CL_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure defines the savings associated with connected lighting that allows for remote user control through a smart device and/or smart hub.

### Definition of Baseline Condition

The baseline condition is the efficient, i.e., LED non-connected version of the lamp.

### Definition of Efficient Condition

The efficient condition is lighting that is controlled by a smart device and/or home energy hub. The savings for this measure are the estimated incremental control savings compared to a non-connected efficient lamp. Savings come from both reduced hours of operation and from dimming.

### Annual Energy Savings Algorithm

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

*Where:*

*WattsEE* = *Actual LED wattage.*

*HOURS* = *Average hours of use per year:*

| Installation Location | Daily Hours | Annual Hours |
|---|---|---|
| Residential interior and in-unit Multi Family | 1.86 | 679[45] |
| Multi Family Common Areas | 16.3 | 5,950[46] |
| Unknown | 1.86 | 679[47] |

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

---

[45] Based on Navigant Consulting, "EmPOWER Residential Lighting Program: 2016 Residential Lighting Inventory and Hours of Use Study" August 31, 2017, page 13. The HOU value is for an efficient lamp.

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

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

*= 0.49* [48]

*ISR* *= In Service Rate or percentage of units rebated that get installed.*
*= 0.98*[49]

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

= 1 - ((HF / ηHeat) * %ElecHeat)

*If unknown assume 0.899*[50]

*HF* *= Heating Factor or percentage of light savings that must be heated*
*= 47%*[51] *for interior or unknown location*
*= 0% for exterior or unheated location*

*ηHeat* *= Efficiency in COP of Heating equipment*
*= actual. If not available, use*[52]*:*

| System Type | Age of Equipment | HSPF Estimate | ηHeat (COP Estimate) |
|---|---|---|---|
| Heat Pump | Before 2006 | 6.8 | 2.00 |
| | 2006 - 2014 | 7.7 | 2.26 |
| | 2015 on | 8.2 | 2.40 |
| Resistance | N/A | N/A | 1.00 |
| Unknown | N/A | N/A | 1.74[53] |

---

[48] Average of two studies. Navigant Consulting. Department of Energy Solid-State Lighting Program. Energy Savings Estimates of Solid-State Lighting in General Illumination Lighting Applications. September 2016. This study estimates a 71% energy savings from connected lighting in residential applications. (Table F-4). Efficiency Vermont. Smart Lighting & Smart Hub. DIY Install: Does it Yield. August 2016. This study estimates reductions in hours of use of up to 27%. Additionally, the metering study saw significant amounts of dimming of lamps that were on non-dimming circuits, but did not quantify the savings associated with this consumer action.

[49] First year ISR of 0.9 (EMPOWER MD Lighting Study, EY5). Assume lifetime ISR of 0.99 (2006-2008 California Residential Lighting Evaluations, and used in the Uniform Methods Project). Assume half of bulbs not installed in year one are installed in year two, and the other half in year three. Using a discount rate of 5%, this gives 0.90 + 0.045 * 0.95 + 0.045 * 0.95^2 = 0.98

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

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

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

[53] Calculation assumes 59% Heat Pump and 41% Resistance which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey. Assume heat pump baseline of 7.7 HSPF.

*%ElecHeat* = *Percentage of home with electric heat*

| Heating fuel | %ElecHeat |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |
| Unknown | 37.5%[54] |

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

| | $WHFe_{Cool}$ |
|---|---|
| Building with cooling | 1.087[55] |
| Building without cooling or exterior | 1.0 |
| Unknown | 1.077[56] |

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

*=0.0004[57] x 8760 x 75%[58] = 2.63 kWh*

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

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

*= 0.49[59]*

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

---

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

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

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

[57] Lockheed Martin Energy. Home Energy Management System Savings Validation Pilot. Final Report. Prepared for New York State Energy Research and Development Authority. November 2017. p32.

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

[59] See footnote 4.

| | WHFd |
|---|---|
| Building with cooling | *1.19*[60] |
| Building without cooling or exterior | 1.0 |
| Unknown | *1.17*[61] |

*CF* = *Summer Peak Coincidence Factor for measure*

| Installation Location | Type | Coincidence Factor (CF) |
|---|---|---|
| Residential interior and in-unit Multi Family | Utility Peak CF | 0.059[62] |
| | PJM CF | 0.058[63] |
| Multi Family Common Areas | PJM CF | 0.86[64] |
| Exterior | PJM CF | 0.018[65] |
| Unknown | Utility Peak CF | 0.059 |
| | PJM CF | 0.058 |

**Annual Fossil Fuel Savings Algorithm**

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

ΔMMBTUPenalty = ((kWconnected * HOURS * SVGe * ISR * HF * 0.003412) / ηHeat)

*Where:*

*HF* = *Heating Factor or percentage of light savings that must be heated*
= *47%*[66] *for interior or unknown location*
= *0% for exterior or unheated location*

*0.003412* =*Converts kWh to MMBTU*

*ηHeat* = *Efficiency of heating system*
=*80%*[67]

---

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

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

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

[63] Ibid.

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

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

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

[67] Minimum federal standard for residential furnaces.

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

| Heating fuel | %FossilHeat |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |
| Unknown | 62.5%[68] |

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 15 years.[69]

---

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

[69] ENERGY STAR lifetime minimum requirement for a 15,000-hour A-lamp LED at 679 hrs./yr. ENERGY STAR Program Requirements. Product Specification for Lamps (Light Bulbs). Eligibility Criteria 2.1. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf. While the Maryland HOU estimate yields a 22-year lifetime, this value has been derated to account for obsolescence and removal prior to technical end-of-life.

*Refrigeration End Use*

# Freezer

**Unique Measure Code(s): RS_RF_TOS_RPPFRZ_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the promotion of residential freezers meeting the ENERGY STAR criteria through retail channels and through upstream efforts such as the ENERGY STAR Retail Products Program. In the measure, a freezer meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard (NAECA). Energy usage specifications are defined in the tables below (note, AV is the freezer Adjusted Volume and is calculated as 1.76*Total Volume):[70]

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

### Definition of Baseline Condition

The baseline equipment is assumed to be a freezer model that meets the federal minimum standard for energy efficiency. The standard varies depending on the type of the freezer (chest or upright freezer), its size category (full or compact) and other attributes (defrost type and presence of through the door ice) and is defined in the tables below.

### Definition of Efficient Condition

The efficient equipment is defined as a freezer meeting the freezer efficiency specifications of ENERGY STAR, as calculated below.[71]

### Annual Energy Savings Algorithm

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

*Where:*

$kWh_{BASE}$ = *Baseline kWh consumption per year*
= *As calculated in the table below based on the product class and adjusted volume (AV)*

$kWh_{ESTAR}$ = *ENERGY STAR kWh consumption per year*
=*As calculated in the table below based on the product class and adjusted volume (AV)*

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

[71] https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf

| Product Class | Baseline Annual kWh Consumption (kWh/year)[72] | ENERGY STAR Annual kWh Consumption (kWh/year)[73] |
|---|---|---|
| ***Full-Size Freezers*** | | |
| 8. Upright freezers with manual defrost. | 5.57*AV + 193.7 | 5.01 * AV + 174.3 |
| 9. Upright freezers with automatic defrost without an automatic icemaker. | 8.62*AV + 228.3 | 7.76 * AV + 205.5 |
| 9I. Upright freezers with automatic defrost with an automatic icemaker. | 8.62*AV + 312.3 | 7.76 * AV + 289.5 |
| 9-BI. Built-In Upright freezers with automatic defrost without an automatic icemaker. | 9.86*AV + 260.9 | 8.87 * AV + 234.8 |
| 9I-BI. Built-in upright freezers with automatic defrost with an automatic icemaker. | 9.86*AV + 344.9 | 8.87 * AV + 318.8 |
| 10. Chest freezers and all other freezers except compact freezers. | 7.29*AV + 107.8 | 6.56 * AV + 97.0 |
| 10A. Chest freezers with automatic defrost. | 10.24*AV + 148.1 | 9.22 * AV + 133.3 |
| ***Compact Freezers*** | | |
| 16. Compact upright freezers with manual defrost. | 8.65*AV + 225.7 | 7.79 * AV + 203.1 |
| 17. Compact upright freezers with automatic defrost. | 10.17*AV + 351.9 | 9.15 * AV + 316.7 |
| 18. Compact chest freezers. | 9.25*AV + 136.8 | 8.33 * AV + 123.1 |

If insufficient information is available to use the algorithms above, then use the default values below.[74]

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[72] https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8

[73] https://www.energystar.gov/ia/partners/product_specs/program_reqs/Refrigerators_and_Freezers_Program_Requirements_V5.0.pdf

[74] The weighted average unit energy savings is calculated using the market share of upright and chest freezers. The assumed market share, as presented in the table above, comes from 2011 NIA-Frz-2008 Shipments data.

| Product Category[75] | Adj. Volume Use | $kWh_{BASE}$ | $kWh_{ESTAR}$ | kWhEstar + 5% | kWh - Estar | kWh – Estar + 5% | Weighting for unknown configuration |
|---|---|---|---|---|---|---|---|
| Upright Freezer | 24.4 | 439 | 395 | 375 | 43.78 | 64 | 36.74% |
| Chest Freezer | 18.0 | 239 | 215 | 204 | 23.97 | 35 | 63.26% |
| Weighted Average | | 313 | 281 | 267 | 31.25 | 46 | 100% |

### Summary Coincident Peak kW Savings Algorithm

ΔkW = (ΔkWh/8760) * TAF * LSAF

*Where:*

TAF = Temperature Adjustment Factor
= 1.23 [76]
LSAF = Load Shape Adjustment Factor
= 1.15 [77]

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 11 years[78].

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[75] Savings values come from ENERGY STAR Calculations. See 'RPP Product Analysis 9-23-15.xlsx'

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

[77] 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).

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

# Refrigerator, Time of Sale

**Unique Measure Code(s): RS_RF_TOS_REFRIG_V0414**
**Effective Date:**
**End Date: TBD**

**Measure Description**

This measure relates to the purchase and installation of a new refrigerator meeting either ENERGY STAR or Consortium for Energy Efficiency (CEE) TIER 2 or TIER 3 specifications (defined as requiring >= 10%,>= 15% or >= 20% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The algorithms for calculating Federal Baseline consumption are provided below.[79] Adjusted Volume is calculated as the fresh volume + (1.63 * Freezer Volume). This is a time of sale measure characterization.

| Product Category | Federal Baseline Maximum Energy Usage in kWh/year[80] |
|---|---|
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 6.79AV + 193.6 |
| 2. Refrigerator-Freezer--partial automatic defrost | 7.99AV + 225.0 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 8.07AV + 233.7 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 8.51AV + 297.8 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 8.85AV + 317.0 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 8.40AV + 385.4 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | 8.54AV + 432.8 |

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

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

**Definition of Baseline Condition**

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

**Definition of Efficient Condition**

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

**Annual Energy Savings Algorithm**

$$\Delta kWh = kWhBASE * ES$$

*Where:*

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

*ES = Annual energy savings of energy efficient unit. ES is 10% for ENERGY STAR Units, 15% for CEE Tier 2 Units, and 20% for CEE Tier 3 Units.*

Illustrative example – do not use as default assumption

A 14 cubic foot ENERGY STAR Refrigerator and 6 cubic foot Freezer, with automatic defrost with side-mounted freezer without through-the-door ice service:

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

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8:[81]

| Product Category | New Baseline $UEC_{BASE}$ | New Efficient $UEC_{EE}$ | | | ΔkWh | | | Product Category Weighting (%) |
|---|---|---|---|---|---|---|---|---|
| | | ENERGY STAR | CEE T2 | CEE T3 | ENERGY STAR | CEE T2 | CEE T3 | |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 368.8 | 331.9 | 313.5 | 295.0 | 36.9 | 55.3 | 73.8 | 0.27 |

---

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

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2. Refrigerator-Freezer--partial automatic defrost | 431.1 | 388.0 | 366.5 | 344.9 | 43.1 | 64.7 | 86.2 | 0.27 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 441.9 | 397.7 | 375.6 | 353.5 | 44.2 | 66.3 | 88.4 | 57.24 |
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 517.4 | 465.6 | 439.8 | 413.9 | 51.7 | 77.6 | 103.5 | 1.40 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 545.3 | 490.8 | 463.5 | 436.3 | 54.5 | 81.8 | 109.1 | 16.45 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 602.1 | 541.9 | 511.8 | 481.7 | 60.2 | 90.3 | 120.4 | 0.27 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with | 653.1 | 587.8 | 555.2 | 522.5 | 65.3 | 98.0 | 130.6 | 24.10 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| through-the-door ice service | | | | | | | | |

If product category shares are unknown [82] assume annual energy savings of 51.1 kWh for ENERGY STAR, 76.7 kWh for CEE T2, and 102.2 kWh for CEE Tier 3.

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

TAF = Temperature Adjustment Factor

= 1.23 [83]

LSAF = Load Shape Adjustment Factor

= 1.15 [84]

If volume is unknown, use the following defaults:

| Product Category | ΔkW | | |
|---|---|---|---|
| | ENERGY STAR | CEE T2 | CEE T3 |
| 1. Refrigerators and Refrigerator-freezers with manual defrost | 0.006 | 0.009 | 0.012 |
| 2. Refrigerator-Freezer--partial automatic defrost | 0.007 | 0.010 | 0.014 |
| 3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost | 0.007 | 0.011 | 0.014 |

---

[82] Unknown configuration is based upon a weighted average of the different configurations. Data is taken from the 2011 DOE Technical Support Document (http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128). Projected product class market shares from pages 9-12 for year 2014. See ‘Refrigerator default calcs.xls’ for more details.

[83] 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.

[84] 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).

| | | | |
|---|---|---|---|
| 4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service | 0.008 | 0.013 | 0.017 |
| 5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service | 0.009 | 0.013 | 0.018 |
| 6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service | 0.010 | 0.015 | 0.019 |
| 7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service | 0.011 | 0.016 | 0.021 |

If product category is unknown assume 0.008 kW for ENERGY STAR and 0.012 kW for CEE Tier 2, and 0.016 kW for CEE Tier 3.

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 12 Years.[85]

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

# Refrigerator, Early Replacement

**Unique Measure Code(s): RS_RF_EREP_REFRIG_0414**
**Effective Date: July 2014**
**End Date: TBD**

### Measure Description

This measure relates to the early removal of an existing inefficient Refrigerator unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR or CEE Tier 2 or 3 qualifying unit. This measure is suitable for a Low Income or a Home Performance program.

Savings are calculated between the existing unit and the new efficient unit consumption during the assumed remaining life of the existing unit, and between a hypothetical new baseline unit and the efficient unit consumption for the remainder of the measure life.

### Definition of Baseline Condition

The baseline condition is the existing inefficient refrigerator unit for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard.

### Definition of Efficient Condition

The efficient condition is a new refrigerator meeting either the ENERGY STAR, CEE TIER 2, or CEE Tier 3 efficiency standards (defined as 10%, 15%, or 20% above federal standards respectively).

### Annual Energy Savings Algorithm

Remaining life of existing unit (first 4 years[86])

$$\Delta kWh = kWhEXIST - kWhEE$$

Remaining measure life (next 8 years)

$$\Delta kWh = kWhBASE - kWhEE$$

*Where:*

*kWhEXIST* = *Annual energy consumption of existing unit*
= *1146* [87]

kWhBASE = *Annual energy consumption of new baseline unit*

= *511.7*[88]

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

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

[88] kWh assumptions based on using the NAECA algorithms in each product class and calculating a weighted average of the different configurations. Data for weighting is taken from the 2011 DOE Technical Support Document

*kWhEE = Annual energy consumption of ENERGY STAR unit*

*=*

*= 460.8*[89]

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

*= 435.2*[90]

*Or=Annual Energy consumption of CEE Tier 3 unit*

*= 409.4*

| Efficient unit specification | First 4 years ΔkWh | Remaining 8 years ΔkWh | Equivalent Mid Life Savings Adjustment (after 4 years) | Equivalent Weighted Average Annual Savings[91] |
|---|---|---|---|---|
| ENERGY STAR | 685.2 | 50.9 | 7.4% | 304.7 |
| CEE T2 | 710.8 | 76.5 | 10.8% | 330.3 |
| CEE T3 | 736.6 | 102.3 | 13.9% | 356.0 |

**Summary Coincident Peak kW Savings Algorithm**

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

*Where:*

TAF = Temperature Adjustment Factor

= 1.23 [92]

LSAF = Load Shape Adjustment Factor

= 1.15 [93]

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(http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128). Projected product class market shares from pages 9-12 for year 2014. See ‘Refrigerator default calcs.xls’ for more details.

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

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

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

92 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.

93 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).

| Efficient unit specification | First 4 years ΔkW | Remaining 8 years ΔkW | Equivalent Mid Life Savings Adjustment (after 4 years) | Equivalent Weighted Average Annual Savings |
|---|---|---|---|---|
| ENERGY STAR | 0.111 | 0.008 | 7.4% | 0.049 |
| CEE T2 | 0.115 | 0.012 | 10.8% | 0.054 |
| CEE T3 | 0.119 | 0.017 | 13.9% | 0.058 |

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 12 Years. [94]

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

# Refrigerator and Freezer, Early Retirement

**Unique Measure Code(s): RS_RF_ERET_REFRIG_0420, RS_RF_ERET_FREEZE_0420**
**Effective Date: April 2020**
**End Date: TBD**

**Measure Description**

This measure involves the removal of an existing inefficient refrigerator[95] 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[96].

The best approach to determine per-unit energy savings for refrigerator and freezer early retirement is to calculate savings using the algorithms below and using unit characteristics derived from program tracking data. This approach will result in the most accurate ex ante savings because it will reflect changes in the characteristics of participant appliances.

However, Maryland utilities may prefer to apply default savings due to the complexity of the energy calculations here and the potential difficulty in gathering the required inputs. While this approach is acceptable, it adds uncertainty to gross realized savings ratios since the evaluated savings will reflect the participant unit characteristics. If utilities choose to apply default savings, or if the program tracking data and other savings inputs are not available, utilities may use the energy and demand values in the table below.

**Default Values for Annual Energy and Demand Savings**

| Utility | Refrigerator Early Retirement Default Annual Energy Savings (kWh) | Refrigerator Early Retirement Default Demand Savings (kW) | Freezer Early Retirement Default Annual Energy Savings (kWh) | Freezer Early Retirement Default Demand Savings (kW) |
|---|---|---|---|---|
| BGE | 1,099 | 0.164 | 687 | 0.103 |
| Pepco | 1,079 | 0.162 | 700 | 0.105 |
| Delmarva Power | 1,087 | 0.163 | 650 | 0.097 |
| PE | 1,052 | 0.157 | 692 | 0.104 |

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[95] 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.

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

| | | | | |
|---|---|---|---|---|
| SMECO | 1,129 | 0.169 | 670 | 0.100 |

*Source:* Cadmus analysis in 2018 P1

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

**Definition of Efficient Condition**
The existing inefficient refrigerator is removed from service and not replaced.

**Annual Energy Savings Algorithm**

**Refrigerators**:
Energy savings for retired refrigerators are based upon a linear regression model using the following coefficients[97]:

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Intercept | 0.80460 |
| Age (years) | 0.02107 |
| Pre-1990 (=1 if manufactured pre-1990) | 1.03605 |
| Size (cubic feet) | 0.05930 |
| Dummy: Single Door (=1 if single door) | -1.75138 |
| Dummy: Side-by-Side (= 1 if side-by-side) | 1.11963 |
| Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit) | 0.55990 |
| Interaction: Located in Unconditioned Space x HDD/365.25 | -0.04013 |
| Interaction: Located in Unconditioned Space x CDD/365.25 | 0.02622 |

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

*Where:*

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

*HDD* = *Heating Degree Days*

= *dependent on location. Use actual for location or defaults below*[98]

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

*CDD* = *Cooling Degree Days*

= *dependent on location. Use actual for location or defaults below*[99]

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

*Part Use Factor* = *To account for those units that are not running throughout the entire year as reported by the customer. Default of 0.95 for refrigerators and 0.86 for freezers.*[100]

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

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

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

$= 1{,}098$ kWh

**Freezers:**

Energy savings for freezers are based upon a linear regression model using the following coefficients[101]:

| Independent Variable Description | Estimate Coefficient |
|---|---|
| Intercept | -0.95470 |

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[98] The 10-year average annual heating degree day value is calculated for each location, using a balance point of 65 degrees as used in the EmPower Appliance Recycling Evaluation.

[99] Ibid.

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

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

| | |
|---|---|
| Age (years) | 0.0453 |
| Pre-1990 (=1 if manufactured pre-1990) | 0.54341 |
| Size (cubic feet) | 0.12023 |
| Chest Freezer Configuration (=1 if chest freezer) | 0.29816 |
| Interaction: Located in Unconditioned Space x HDD/365.25 | -0.03148 |
| Interaction: Located in Unconditioned Space x CDD/365.25 | 0.08217 |

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

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

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

ΔkWh = [-0.95470 + (23.79 * 0.04536) + (0.46 * 0.54341) + (15.86 * 0.12023) + (0.21 * 0.29816) + (6.83 * -0.03148) + (1.80 * 0.08217)] * 365.25 * 0.86

= 715 kWh

**Summer Coincident Peak kW Savings Algorithm**

ΔkW = (ΔkWh/8760) * TAF * LSAF

*Where:*

TAF = Temperature Adjustment Factor
= 1.23 [102]

LSAF = Load Shape Adjustment Factor
= 1.066 [103]

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

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[102] 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.

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

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

Refrigerator:

$$\Delta kW = 1098/8760 * 1.23 * 1.066$$

$$= 0.164 \text{ kW}$$

Freezer:

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

$$= 0.107 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 8 Years.[104]

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

*Heating Ventilation and Air Conditioning (HVAC) End Use*

# Room Air Conditioner, Time of Sale

**Unique Measure Code(s): RS_HV_TOS_RA/CES_0420 RS_HV_TOS_RA/CT2_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the purchase (time of sale) and installation of a room air conditioning unit that meets the ENERGY STAR minimum qualifying efficiency specifications presented below.

| Product Type and Class (BTU/hour) | | Federal Standard with louvered sides (CEER) | Federal Standard without louvered sides (CEER) | ENERGY STAR with louvered sides (CEER) | ENERGY STAR without louvered sides (CEER) |
|---|---|---|---|---|---|
| Without Reverse Cycle | < 8,000 | 11.0 | 10.0 | 12.1 | 11.0 |
| | 8,000 to 10,999 | 10.9 | 9.6 | 12.0 | 10.6 |
| | 11,000 to 13,999 | 10.9 | 9.5 | 12.0 | 10.5 |
| | 14,000 to 19,999 | 10.7 | 9.3 | 11.8 | 10.2 |
| | 20,000 to 24,999 | 9.4 | 9.4 | 10.3 | 10.3 |
| | 25,000 to 27,999 | 9.0 | 9.4 | 10.3 | 10.3 |
| | >=28,000 | 9.0 | 9.4 | 9.9 | 10.3 |
| With Reverse Cycle | <14,000 | NA | 9.3 | NA | 10.2 |
| | >= 14,000 | NA | 8.7 | NA | 9.6 |
| | <20,000 | 9.8 | NA | 10.8 | NA |
| | >=20,000 | 9.3 | NA | 10.2 | NA |
| Casement only | | 9.5 | | 10.5 | |
| Casement-Slider | | 10.4 | | 11.4 | |

### Definition of Baseline Condition

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

### Definition of Efficient Condition

The efficient condition is a window AC unit that meets the ENERGY STAR v4.0.

### Annual Energy Savings Algorithm

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

*Where:*

*Hours = Run hours of Window AC unit*

*= 325* [105]
*BTU/hour = Size of rebated unit*
*When available, the actual size of the rebated unit should be used in the calculation. In the absence of this data, the following default value can be used:*
*= 8500* [106]
*CEERbase = Efficiency of baseline unit in BTUs per Watt-hour*
*= Actual (see table above)*
*If average deemed value required use 10.9* [107]
*CEERee = Efficiency of ENERGY STAR unit in BTUs per Watt-hour*
*= Actual*
*If average deemed value required use 12.0*[108] *for an ENERGY STAR unit*

Using deemed values above:

$\Delta kWH$
= (325 * 8500 * (1/10.9 – 1/12)) / 1000
= 23.2 kWh

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*CF = Summer Peak Coincidence Factor for measure*
$CF_{SSP}$ *= Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
*= 0.31* [109]
$CF_{PJM}$ *= 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*[110]

Using deemed values above:

$\Delta kW_{SSP}$
= (8500 * (1/10.9 – 1/12)) / 1000 * 0.31

---

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

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

[105] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (744 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

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

l Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf).

$= 0.022$ kW

$\Delta kW_{PJM}$

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

$= 0.021$ kW

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 12 years.[111]

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[111] Based on Appliances Magazine – Market Research - The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013 (Dec. 2013. http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.pdf

# ENERGY STAR Central A/C

**Unique Measure Code(s): RS_HV_TOS_CENA/C_0420, RS_HV_EREP_CENA/C_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a new Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below.

| Efficiency Level | SEER Rating | EER Rating |
|---|---|---|
| Federal Standard | 14 | 11.8[112] |
| ENERGY STAR | 15 | 12.5 |

This measure could relate to:

a) Time of Sale – the installation of a new Central AC system meeting ENERGY STAR specifications replacing an existing unit at the end of its useful life or the installation of a new system in a new home. Most units bought at a store receiving prescriptive incentives are considered time of sale.

b) Early Replacement – the early removal of an existing, functioning unit prior to its natural end of life and replacement with an ENERGY STAR unit. Savings are calculated between existing unit and efficient unit consumption during the assumed remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

NOTE: Maryland Utilities should assume that 34% of the rebated CACs and ASHPs are Early Replacement, and 66% are Time Of Sale.[113] The team will calculate total savings for each reported CAC and ASHP using a multi-baseline approach, as shown in the equations:

*Total (program period) kWh Savings = TOS kWh Savings x 66% + ER kWh Savings x 34%*

*Total (program period) kW Savings = TOS kW Savings x 66% + ER kW Savings x 34%*

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Comprehensive building efficiency improvements will reduce load, and may lead to downsizing of space conditioning equipment. To properly account for these interactive effects, energy modeling should be performed and those results should be used for savings attribution in place of savings algorithms shown here. Effects of HVAC downsizing can be attributed to either weatherization or HVAC, but not both.

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

[113] EmPOWER 2018 Participant Survey Memo HVAC Downstream-Final.

**Definition of Baseline Condition**

The baseline condition for the Time of Sale is a central air conditioning ducted split system that meets the minimum Federal standards as presented above.

The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the new, efficient equipment measure life. If the existing equipment efficiency is unknown, use the prevailing federal efficiency standard based on age per table below for split systems.

Note that to be characterized as early replacement, the age of the unit must not exceed the measure life of 18 years.

| Split System Air Conditioner Federal Baselines for Southeast[114] | |
|---|---|
| **Manufacture Date** | **SEER** |
| January 1993 through January 2006 | 10.0 |
| February 2006 through December 2014 | 13.0 |
| After January 1 2015 | 14.0 |

**Definition of Efficient Condition**

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

**Annual Energy Savings Algorithm**

Time of Sale:

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

Early replacement[115]:

ΔkWH for remaining life of existing unit:

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

115 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new base to efficient savings)/(existing to efficient savings).

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

ΔkWH for balance of measure life:

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

*Where:*

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

**Maryland Utility-Specific EFLH Values**[116]

| | BGE | Pepco | Delmarva Power | PE | SMECO |
|---|---|---|---|---|---|
| CAC Cooling EFLH | 568 | 523 | 539 | 515 | 565 |

| *Location* | *Run Hours* |
|---|---|
| *Wilmington, DE* | *524* [117] |
| *Washington, DC* | *681* |

*BTUHexist* = *Size of existing equipment in BTU/hour (tons x 12,000BTU/hr)*
= *Actual installed*

*BTUHee* = *Size of new efficient equipment in BTU/hour (tons x 12,000BTU/hr)*

*SEERbase* = *Seasonal Energy Efficiency Ratio Efficiency of baseline unit*
= *14* [118]

*SEERexist* = *Seasonal Energy Efficiency Ratio of existing unit (kBTU/kWh)*
= *Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11.*[119]

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[116] Maryland-specific values that the evaluation team calculated in EY3 based on EY1 and EY3 metering data

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

[118] Minimum Federal Standard.

[119] Based on Itron and Cadmus unpublished analysis of standard efficiency units by age of unit from Energy Information Administration, Residential Energy Consumption Survey, 2015, AHRI historical shipments data (http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx), and Energy Star historical shipments data (https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?52f9-67a), and mortality curve assumptions drawn from Cory Welch, Estimating the Useful Life of Residential Appliances, ACEEE Summer Study 2010 paper (http://aceee.org/files/proceedings/2010/data/papers/1977.pdf).

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

*Fan Circulation* = Energy savings associated with the installation of an efficient fan motor
= *91.3*[120]

Illustrative example – do not use as default assumption

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

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

= 93 kWh

Early Replacement example where there is a "right-sizing" adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): a 3-ton, 11 SEER unit replaced with a 2-ton with SEER rating of 15 in Baltimore:

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

= 907 kWh

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

= 526 kWh

## Summer and Winter PJM Coincident Peak kW Savings Algorithm

$$\Delta kW_{PJM\ summer} = \frac{BTU_c}{1{,}000\,\frac{BTU}{kBTU}} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF_{adj}$$

$$\Delta kW_{PJM\ winter} = \frac{BTU_h}{1{,}000\,\frac{BTU}{kBTU}} \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}}\right) \times CF_{adj}$$

The table below lists the CF adjustment factors that Maryland utilities should use to calculate winter and summer PJM peak demand savings by for the different measure categories. Parameters in Table 2 replace the peak coincidence factor ($CF_{ssp}$ = 0.66) in the TRM demand savings algorithm. The new summer and winter parameters (adjusted CF values, $CF_{adj}$) are

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[120] EmPOWER Maryland 2019-2020 Installation Year Deemed Savings Memo

unique to each utility and measure category. These enable the calculation of PJM peak demand savings using the standard algorithm and the rated efficiency and capacity values reported in utility's tracking databases. The algorithms **Error! Reference source not found.** and **Error! Reference source not found.** and the new adjustment factors ($CF_{adj}$) replace the ΔkW/ton method used to calculate utility demand savings (see section 0). Note GSHPs use coefficient of performance (COP) to describe heating efficiency. The HSPF value in **Error! Reference source not found.** may be estimated for GSHPs by assuming COP x 3.412 = HSPF.

**Table 2. Factors ($CF_{adj}$) for Summer and Winter Demand Savings Algorithm**

| Utility | ASHP SEER 16 | ASHP SEER 16 Winter | ASHP SEER 18 | ASHP SEER 18 Winter | CAC SEER 16 | CAC SEER 18 | GSHP | GSHP Winter |
|---|---|---|---|---|---|---|---|---|
| BGE | 1.09 | 0.73 | 1.08 | 0.55 | 0.84 | 0.81 | 0.59 | 0.53 |
| DPL | 0.69 | 0.53 | 0.93 | 0.29 | 0.68 | 0.84 | 0.59 | 0.55 |
| Pepco | 0.98 | 0.94 | 1.31 | 0.60 | 0.94 | 0.91 | 0.61 | 0.62 |
| SMECO | 1.15 | 0.89 | 1.22 | 0.62 | 0.81 | 1.05 | 0.62 | 0.73 |
| PE | 0.86 | 0.87 | 1.09 | 0.71 | 0.64 | 0.76 | 0.56 | 0.55 |

*Where:*

*EERbaseline = Energy Efficiency Ratio Efficiency of baseline unit*
*= 11.8*
*EERee = EER Efficiency of existing unit*
*= Actual EER of unit should be used, if EER is unknown, use 9.9*[121]
*EERee = Energy Efficiency Ratio Efficiency of ENERGY STAR unit*
*= Actual installed*
$CF_{adj}$ *= Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday) see table.*

Illustrative example – do not use as default assumption.

Time of Sale example: a 3-ton unit with efficient EER rating of 12.5 upgraded from lower efficiency to higher, with same size unit:

$$\Delta kW_{SSP} = ((36000 \times 1/11.8) - (36000 \times 1/12.5)) / 1000 \times 0.69$$

$$= 0.12 \text{ kW}$$

$$\Delta kW_{PJM} = ((36000 \times 1/11.8) - (36000 \times 1/12.5)) / 1000 \times 0.66$$

$$= 0.11 \text{ kW}$$

Early Replacement example where there is a "right-sizing" adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): an existing 3-ton unit with EER 9.9 is replaced by a 2-ton unit with EER rating of 12.5 in Baltimore:

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[121] Based on SEER of 11, using a formula to give 9.9 EER. The Federal Standard does not include an EER requirement, so it is approximated with this formula: ($-0.02 * SEER^2$) + ($1.12 * SEER$). See Wassmer, M. (2003), "A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations," Master's Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

ΔkW for remaining life of existing unit:

$\Delta kW_{SSP}$ = ((36000 x 1/9.9) – (24000 x 1/12.5)) / 1000 x 0.69

= 1.18 kW

$\Delta kW_{PJM}$ = ((36000 x 1/9.9) – (24000 x 1/12.5)) / 1000 x 0.66

= 0.1.13 kW

ΔkW for remaining measure life:

$\Delta kW_{SSP}$ = ((36000 x 1/11.8) – (24000 x 1/12.5)) / 1000 x 0.69

= 0.78 kW

$\Delta kW_{PJM}$ ((36000 x 1/11.8) – (24000 x 1/12.5)) / 1000 x 0.66

= 0.75 kW

**Utility Demand Savings**

**Utility-Specific ΔkW/Ton Values**

| | BGE | Pepco | Delmarva Power | SMECO | PE |
|---|---|---|---|---|---|
| Utility CAC | 0.097 | 0.100 | 0.095 | 0.100 | 0.087 |
| Utility HP | 0.118 | 0.120 | 0.115 | 0.120 | 0.107 |

The average nameplate efficiency of rebated systems may be different from the average nameplate efficiency of the systems metered in 2010 and 2012,[122] which were used to determine the values in the table above. Utilities should adjust the ΔkW/ton values to account for actual EER values reported. Utilities should use the following algorithm to determine utility-specific demand savings for time of sale (TOS) or replace on burnout savings:

$$kW\ saved = \frac{BTU_c}{12{,}000\frac{BTU}{ton}} \times \frac{EER_{ee}}{Metered\ EER} \times \Delta\frac{kW}{ton}$$

Utilities should use this equation for early retirements:

kW saved = (TOS kW Savings) / (TOS kWh Savings) X (ER kWh Savings)

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[122] For metering details, see: 2011 Evaluation Report, Chapter 6: Residential Heating, Ventilation and Air Conditioning Program (HVAC), final draft dated March 8, 2012; and EmPOWER Maryland Final Evaluation Report, Evaluation Year 4 (June 1, 2012 – May 31, 2013), Residential HVAC Program, revised final report dated June 23, 2014.

Where:

**Deemed EER** = 12.943 for CACs

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 18 years.[123]

Remaining life of existing equipment is assumed to be 6 years[124] unless otherwise known.

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[123] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.

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

# Air Source Heat Pump

**Unique Measure Code: RS_HV_TOS_ASHP_0420, RS_HV_EREP_ASHP_0420,**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a new Air Source Heat Pump split system meeting ENERGY STAR efficiency standards presented below:

| Efficiency Level | HSPF | SEER Rating | EER Rating[125] |
|---|---|---|---|
| Federal Standard as of 1/1/2015 | 8.2 | 14 | 11.8[126] |
| ENERGY STAR | 8.5 | 15 | 12.5 |

This measure could relate to:

a) Time of Sale – the installation of a new Air Source Heat Pump system meeting ENERGY STAR specifications replacing an existing unit at the end of its useful life or the installation of a new system in a new home. Most units bought at a store receiving prescriptive incentives are considered time of sale.

b) Early Replacement – the early removal of existing functioning electric heating and cooling heat pump system prior to its natural end of life and replacement with an ENERGY STAR unit. Dual baseline savings are calculated between existing unit and efficient unit consumption during the assumed remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

NOTE: Maryland Utilities should assume that 34% of the rebated CACs and ASHPs are Early Replacement, and 66% are Time Of Sale.[127] The team will calculate total savings for each reported CAC and ASHP using a multi-baseline approach, as shown in the equations:

*Total (program period) kWh Savings = TOS kWh Savings x 66% + ER kWh Savings x 34%*

*Total (program period) kW Savings = TOS kW Savings x 66% + ER kW Savings x 34%*

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Comprehensive building efficiency improvements will reduce load and may lead to downsizing of space

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

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

[127] EmPOWER 2018 Participant Survey Memo HVAC Downstream-Final.

conditioning equipment. To properly account for these interactive effects, energy modeling should be performed and the results should be used for savings attribution in place of savings algorithms shown here. Effects of HVAC downsizing can be attributed to either weatherization or HVAC, but not both.

**Definition of Baseline Condition**
The baseline condition for the Time of Sale measure is an Air Source Heat Pump split system that meets the minimum Federal standards defined above.

The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline of the same equipment type for the remainder of the new, efficient equipment measure life as provided in the table below.

Note that to be characterized as early replacement, the age of the unit must not exceed the measure life of 18 years.

| Existing Equipment Type | HSPF | SEER Rating | EER Rating |
|---|---|---|---|
| ASHP | 8.2 | 14 | 11.8 |
| Electric Resistance and Central AC | 3.41 | 14 | 11.0 |

**Definition of Efficient Condition**
The efficient condition is an Air Source Heat Pump split system that meets the ENERGY STAR standards defined above or other specifications as determined by the programs.

**Annual Energy Savings Algorithm**
Annual energy savings is the sum of heating and cooling savings.

Time of Sale:

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

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

Early replacement[128]:

ΔkWH for remaining life of existing unit:

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[128] The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).

$$\Delta\text{kWH} = EFLHcool\ x\ \frac{(\text{BTUHCexist / SEERexist}) - (\text{BTUHCee / SEERee})}{1000} + EFLHheat\ x\ \frac{(\text{BTUHHexist / HSPFexist}) - (\text{BTUHHee / HSPFee})}{1000} + Fan\ Circulation$$

ΔkWH for remaining measure life:

$$\Delta\text{kWH} = EFLHcool\ x\ \frac{(\text{BTUHCexist / SEERbasereplace}) - (\text{BTUHCee / SEERee})}{1000} + EFLHheat\ x\ \frac{(\text{BTUHHexist / HSPFbasereplace}) - (\text{BTUHHee / HSPFee})}{1000}$$

*Where:*

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

**Maryland Utility-Specific EFLH Values**[129]

| | BGE | Pepco | Delmarva Power | PE | SMECO |
|---|---|---|---|---|---|
| ASHP/GSHP—Cooling EFLH | 778 | 717 | 739 | 712 | 775 |
| ASHP/GSHP—Heating EFLH | 852 | 883 | 784 | 885 | 815 |

| *Location* | *FLHcool* |
|---|---|
| *Wilmington, DE* | *719*[130] |
| *Washington, DC* | *935* |

*BTUHC$_{exist}$* = *Cooling capacity of existing Air Source Heat Pump (tons x 12,000BTU/hr)*
= *Actual*

*BTUHC$_{ee}$* = *Cooling capacity of new, efficient Air Source Heat Pump (tons x 12,000BTU/hr)*
= *Actual*

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[129] EmPOWER Maryland Final Evaluation Report, Evaluation Year 4, Residential HVAC Program, dated April 4, 2014

[130] Full Load Cooling Hours assumptions for Wilmington, DE and Washington, DC calculated by multiplying the EmPower average Maryland full load hours determined for Maryland (744 from the research referenced below) by the ratio of full load hours in Wilmington, DE (1,015) or Washington, DC (1,320) to Baltimore MD (1,050) from the ENERGY STAR calculator. (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)

*SEERbase* = *Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump*
*= 14*[131]

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

| *Existing Cooling System* | *SEERexist*[132] |
|---|---|
| *Air Source Heat Pump or Central AC* | *11* |
| *No central cooling*[133] | *Make '1/SEERexist' = 0* |

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

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

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

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

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[131] Minimum federal standard

[132] Based on Itron and Cadmus unpublished analysis of standard efficiency units by age of unit from Energy Information Administration, Residential Energy Consumption Survey, 2015, AHRI historical shipments data (http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx), and Energy Star historical shipments data (https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?52f9-67a), and mortality curve assumptions drawn from Cory Welch, Estimating the Useful Life of Residential Appliances, ACEEE Summer Study 2010 paper (http://aceee.org/files/proceedings/2010/data/papers/1977.pdf)

[133] If there is no central cooling in place but the incentive encourages installation of a new ASHP with cooling, the added cooling load should be subtracted from any heating benefit.

| *Location* | FLHheat |
|---|---|
| *Wilmington, DE* | *935*[134] |
| *Baltimore, MD* | *866*[135] |
| *Washington, DC* | *822* |

*BTUHH*$_{exist}$ = *Heating capacity of existing Air Source Heat Pump (tons x 12,000BTU/hr)*
= *Actual*

*BTUHH*$_{ee}$ = *Heating capacity of new, efficient Air Source Heat Pump (tons x 12,000BTU/hr)*
= *Actual*

*HSPFbase* = *Heating Seasonal Performance Factor of baseline Air Source Heat*
= *8.2*[136]

*HSPFexist* = *Heating System Performance Factor*[137] *of existing heating system (kBTU/kWh)*

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

| Air Source Heat Pump Federal Efficiency Standards | |
|---|---|
| **Age** | **HSPF** |
| Before 2006 | 6.8 |
| 2006 - 2014 | 7.7 |
| 2015 - present | 8.2 |

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

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

[136] Minimum Federal Standard

[137] HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within zone 4 which encompasses all of the Mid Atlantic region. There should therefore be no reason to adjust the rated HSPF for geographical/climate variances.

| | |
|---|---|
| Electric Resistance | 3.41[138] |

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

*HSPFbasereplace* = *Baseline Heating System Performance Factor of same, new equipment type as existing (kBTU/kWh)*

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

*Fan Circulation* = Energy savings associated with the installation of an efficient fan motor
= *91.3*[139]

Illustrative example – do not use as default assumption
Time of Sale example: a 3-ton unit with a SEER rating of 15 and HSPF of 8.5 upgraded from lower efficiency to higher, with an equivalent sized unit in Baltimore, MD:

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

= 509 kWh

Early Replacement example where there is a "right-sizing" adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): a 2-ton heat pump with a SEER rating of 15 and HSPF of 8.5 in Baltimore, MD is installed replacing an existing working 3 ton Central AC system with a SEER rating of 11 and electric resistance heating:

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

= 7,942 kWh

ΔkWH (through end of life) =
744 x ((36,000/14) - (24,000/15))/1,000

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[138] Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF
[139] EmPOWER Maryland 2019-2020 Installation Year Deemed Savings Memo

+ 866 x ((36,000/3.41) – (24,000/8.5))/1,000

= 7,420 kWh

### Summer and Winter Coincident Peak kW Savings Algorithms

Time of Sale:

$$\Delta kW_{PJM\ summer} = \frac{BTU_c}{1{,}000\,\frac{BTU}{kBTU}} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF_{adj}$$

$$\Delta kW_{PJM\ winter} = \frac{BTU_h}{1{,}000\,\frac{BTU}{kBTU}} \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{HSPF_{ee}}\right) \times CF_{adj}$$

The table below lists the CF adjustment factors that utilities should use to calculate winter and summer PJM peak demand savings by for the different measure categories. Parameters in the table replace the peak coincidence factor ($CF_{ssp}$ = 0.66) in the previous TRM's demand savings algorithm. The summer and winter parameters (adjusted CF values, $CF_{adj}$) are unique to each utility and measure category. These enable the calculation of PJM peak demand savings using the standard algorithm and the rated efficiency and capacity values reported in utilities' tracking databases. The algorithms in the equations above and the adjustment factors ($CF_{adj}$) replace the ΔkW/ton method used to calculate utility demand savings. Note GSHPs use coefficient of performance (COP) to describe heating efficiency. The HSPF value in the equation above may be estimated for GSHPs by assuming COP x 3.412 = HSPF.

**Factors ($CF_{adj}$) for Summer and Winter Demand Savings Algorithm**

| Utility | ASHP SEER 16 | ASHP SEER 16 Winter | ASHP SEER 18 | ASHP SEER 18 Winter | CAC SEER 16 | CAC SEER 18 | GSHP | GSHP Winter |
|---|---|---|---|---|---|---|---|---|
| BGE | 1.09 | 0.73 | 1.08 | 0.55 | 0.84 | 0.81 | 0.59 | 0.53 |
| DPL | 0.69 | 0.53 | 0.93 | 0.29 | 0.68 | 0.84 | 0.59 | 0.55 |
| Pepco | 0.98 | 0.94 | 1.31 | 0.60 | 0.94 | 0.91 | 0.61 | 0.62 |
| SMECO | 1.15 | 0.89 | 1.22 | 0.62 | 0.81 | 1.05 | 0.62 | 0.73 |
| PE | 0.86 | 0.87 | 1.09 | 0.71 | 0.64 | 0.76 | 0.56 | 0.55 |

**Utility Demand Savings for ASHPs**

The table below shows the utility-specific per ton demand savings values to determine utility demand savings for air-source heat pumps

**Maryland Utility-Specific ΔkW/Ton Values**

| | BGE | Pepco | Delmarva Power | SMECO | PE |
|---|---|---|---|---|---|
| Utility CAC | 0.097 | 0.100 | 0.095 | 0.100 | 0.087 |

| | | | | | |
|---|---|---|---|---|---|
| Utility HP | 0.118 | 0.120 | 0.115 | 0.120 | 0.107 |

The average nameplate efficiency of rebated systems may be different from the average nameplate efficiency of the systems that the evaluation team metered in 2010 and 2012,[140] which were used to determine the values above. Therefore, adjust the ΔkW/ton values to account for actual EER values reported. Utilities should use the following algorithm to determine utility-specific demand savings for time of sale (TOS) or replace on burnout savings:

$$kW\ saved = \frac{BTU_c}{12{,}000\frac{BTU}{ton}} \times \frac{EER_{ee}}{Metered\ EER} \times \Delta\frac{kW}{ton}$$

Utilities should use this equation for early retirements:

kW saved = (TOS kW Savings) / (TOS kWh Savings) X (ER kWh Savings)

Where:

**Deemed EER** = 12.943 for CACs; 12.956 for ASHPs and ductless HPs.

*Total kW Savings = TOS kW Savings x 63% + ER kW Savings x 37%*

The evaluation team will follow the TRM to determine first year (also first six years) gross savings for early replacement measures with EFLH and baseline SEER exceptions noted. Net savings will be adjusted for early replacement, as necessary

\

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 18 years[141].

Remaining life of existing equipment is assumed to be 6 years[142] unless otherwise known.

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[140] For metering details, see: 2011 Evaluation Report, Chapter 6: Residential Heating, Ventilation and Air Conditioning Program (HVAC), final draft dated March 8, 2012; and EmPOWER Maryland Final Evaluation Report, Evaluation Year 4 (June 1, 2012 – May 31, 2013), Residential HVAC Program, revised final report dated June 23, 2014.

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

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

# Ductless Mini-Split Heat Pump

**Unique Measure Code: RS_HV_TOS_MSHP_0518, RS_HV_EREP_ASHP_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the installation of new ENERGY STAR rated ductless “mini-split” heat pump(s) (DMSHP). A ductless mini-split heat pump (DMSHP) is a type of heat pump with an outdoor condensing unit connected via refrigerant line to one or more indoor evaporator coils. Ductless mini-split heat pumps deliver cooling at the same or higher efficiency as standard central AC units, but can also deliver heat. Further, since the units do not require ductwork, they avoid duct losses.

This measure could be installed in either an existing or in a new home and the characterization is designed to allow the calculation of the impact on electric and/or gas consumption following the installation of a DHP system. The characterization requires that the program implementer perform a custom calculation to determine how much existing and supplemental heating and/or cooling load the DHP will replace based on a combination of billing data, the percentage of conditioned space covered by the DMSHP, the existing equipment and its hours of operation, proposed hours of operation, and the size of the conditioned space. Where possible, this should be treated as a custom measure, due to the number of variables needed, including usage patterns and types of baseline systems.

### Definition of Baseline Condition

The baseline condition for early replacement is the existing heating and cooling (if applicable) systems within the home. If cooling equipment is not previously present, it is presumed that some type of cooling equipment would have been installed and the time of sale baseline described next should be used for the cooling baseline assumption.

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

| Year | SEER | EER | HSPF |
|---|---|---|---|
| 2015 | 14 | 8.5[143] | 8.2 |

### Definition of Efficient Condition

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

Utilities should treat new installations as time of sale using the following assumptions, unless the more involved calculations for displacing electric space heat or fossil fuel are to be employed:

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

**Annual Energy Savings Algorithm**

If improving efficiency at time of sale:

$$kWh\ Saved = EFLH_C \times \frac{BTU_c}{1000} \times \left(\frac{1}{SEER_b} - \frac{1}{SEER_{ee}}\right) + EFLH_H \times \frac{BTU_H}{1000} \times \left(\frac{1}{HSPF_b} - \frac{1}{HSPF_{ee}}\right)$$

Where:

$EFLH_c$ = Full load cooling hour value

$EFLH_H$ = Full load heating hour value

BTUc = Cooling capacity Btu/h. If capacity not provided in BTUs, utilities should estimate using nameplate tons: tons x 12,000 Btu/h per ton.

$BTU_H$ = Heating capacity Btu/h. If capacity not provided in BTUs, utilities should estimate using nameplate tons: tons x 12,000 Btu/h per ton.

$SEER_b$ = 14 (TOS); 11 (ER)

$HSPF_b$ = 8.2 (TOS); 6.8 (ER)

**Utility-Specific EFLH Values**

| | BGE | Pepco | Delmarva Power | PE | SMECO |
|---|---|---|---|---|---|
| ASHP/GSHP—Cooling EFLH | 778 | 717 | 739 | 712 | 775 |
| ASHP/GSHP—Heating EFLH | 852 | 883 | 784 | 885 | 815 |

If displacing/replacing electric resistance heat:

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

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

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

If displacing/replacing gas heat:

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

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

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

*Where:*

*CoolingLoadDHP*

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

= *Actual*

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

*Early Replacement* = *Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 11*[144] *for Central AC or 10.7 for Room AC*[145]*. If no cooling exists, assume 14.0.*

*Time of Sale / New Construction = 14.0*[146]

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

= *Actual (kBTU cooling/ kWh consumed)*

*HeatLoadElectricDHP*

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

= *Actual*[147]

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

$DL_{heat}$ = *1 if duct leakage applies based on baseline heating equipment (0 otherwise)*

$\Delta DL_{impr}$ = Duct loss improvement factor, 0.15

*3.412* = *Converts 1/HSPF to 1/COP*

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

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

*If unknown assume 3.412*[148] *for resistance heat,* 7.15[149] for ASHP.

*Time of Sale / New Construction* = *8.2* [150]

*HSPFee* = *Heating Seasonal Performance Factor of ENERGY STAR ductless heat pump*[151]

= *Actual*

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[144] Based on Itron and Cadmus unpublished analysis of standard efficiency units by age of unit from Energy Information Administration, Residential Energy Consumption Survey, 2015, AHRI historical shipments data (http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps.aspx), and Energy Star historical shipments data (https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2015_USD_Summary_Report.pdf?52f9-67a), and mortality curve assumptions drawn from Cory Welch, Estimating the Useful Life of Residential Appliances, ACEEE Summer Study 2010 paper (http://aceee.org/files/proceedings/2010/data/papers/1977.pdf).If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

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

[146] Minimum Federal Standard

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

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

[149] This is estimated based on finding the average HSPF/SEER ratio from the AHRI directory data (using the least efficient models – SEER 12 and SEER 13) – 0.596, and applying to the existing ASHP SEER rating assumption of 12.

[150] Minimum Federal Standard

[151] HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within AHRI climate zone 4 which encompasses all of the Mid Atlantic region. There should therefore be no reason to adjust the rated HSPF for geographic/climate variances.

*HeatLoadGasDHP* = *Heating load (MMBTU) that the DHP will now provide*
= *Actual*[152]
*293.1* = *Converts MMBTU to kWh*
*AFUEexist* = *Efficiency of existing furnace or boiler*
= *Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 84%*[153].
*3.412* = *Converts heat pump HSPF in to COP*

See example calculations at end of characterization.

**Summer PJM Coincident Peak kW Savings Algorithm**

$$\Delta kW = BTUH_{Cool}\ (1/EERbase \times (1 + \Delta DL_{impr} * DL_{cool}) - 1/EERee))/1{,}000 \times CF$$

*Where:*

$BTUH_{Cool}$ = *Cooling capacity in BTUs per hour (tons x 12,000BTU/hr per ton)*
= *Actual*
*EERbase* = *Energy Efficiency Ratio (EER) of Baseline Air Source Heat Pump*
*Early Replacement* = *Use actual EER rating where it is possible to measure or reasonably estimate.*
*If unknown assume 9.9*[154] *for Central AC or 9.7 for Room AC*[155].
*If no cooling is at the home, make 1/EER = 0 (resulting in a negative value i.e. increase in load).*

*Time of Sale / New Construction* = *8.5*[156]

**For Utility Demand Savings:**

$$kW\ saved = \frac{BTU_c}{12{,}000\,\frac{BTU}{ton}} \times \frac{EER_{ee}}{Metered\ EER} \times \Delta\frac{kW}{ton}$$

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

[153] 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%.

[154] Based on SEER of 11, using a formula to give 9.9 EER. The Federal Standard does not include an EER requirement, so it is approximated with this formula: $(-0.02 * SEER^2) + (1.12 * SEER)$. See Wassmer, M. (2003), “A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations,” Master’s Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

[155] Using the assumption of existing unit EER efficiency in the Room Air Conditioner Early Replacement measure, based on Nexus Market Research Inc, RLW Analytics, December 2005; “Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report.”

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

**Maryland Utility-Specific ΔkW/Ton Values**

| | BGE | Pepco | Delmarva Power | SMECO | PE |
|---|---|---|---|---|---|
| Utility CAC | 0.097 | 0.100 | 0.095 | 0.100 | 0.087 |
| Utility HP | 0.118 | 0.120 | 0.115 | 0.120 | 0.107 |

The average nameplate efficiency of rebated systems may be different from the average nameplate efficiency of the systems that the evaluation team metered in 2010 and 2012,[157] which were used to determine the values in **Error! Reference source not found.**. Therefore, the team recommends that utilities adjust the ΔkW/ton values to account for actual EER values reported. Utilities should use the following algorithm to determine utility-specific demand savings for time of sale (TOS) or replace on burnout savings:

$$kW\ saved = \frac{BTU_c}{12{,}000\frac{BTU}{ton}} \times \frac{EER_{ee}}{Metered\ EER} \times \Delta\frac{kW}{ton}$$

Utilities should use this equation for early retirements:

kW saved = (TOS kW Savings) / (TOS kWh Savings) X (ER kWh Savings)

Where:

**Deemed EER** = 12.943 for CACs; 12.956 for ASHPs and ductless HPs.

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

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

$\Delta DL_{impr}$ = Duct loss improvement factor, 0.15

*CF* = *Coincidence Factor for measure. Assumptions for both Central AC and Room AC are provided below. The appropriate selection depends on whether the DHP is being used similarly to a central AC (thermostatically controlled) or a room AC (controlled with need). If unknown assume Room AC.*

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

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[157] For metering details, see: 2011 Evaluation Report, Chapter 6: Residential Heating, Ventilation and Air Conditioning Program (HVAC), final draft dated March 8, 2012; and EmPOWER Maryland Final Evaluation Report, Evaluation Year 4 (June 1, 2012 – May 31, 2013), Residential HVAC Program, revised final report dated June 23, 2014.

*= 0.31* [158]

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

*= 0.3*[159]

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

*= 0.69* [160]

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

*= 0.66* [161]

See example calculations at end of characterization.

**Annual Fossil Fuel Savings Algorithm**

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

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

*Where:*

*HeatLoadGasReplaced*

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

*= Actual*[162]

*AFUEexist* = *Efficiency of existing heating system*

*= Use actual AFUE rating where it is possible to measure or reasonably estimate. If unknown assume 80%*[163] *for early retirement, or 80% for replace on burnouts*[164]*.*

*$DL_{heat}$* = *1 if duct leakage applies based on baseline heating equipment (0 otherwise)*

$\Delta DL_{impr}$ = Duct loss improvement factor = 0.15

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

[159] 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).

160 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.

161 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.

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

163 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%.

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

See example calculations at end of characterization.

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 18 years[165]. If an early replacement measure results in the removal of existing operating heating or cooling equipment, it is assumed that it would have needed replacing in 6 years.

Illustrative examples – do not use as default assumption

Early Replacement:

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

ΔkWH = (CoolingLoadDHP x (1/SEERbase - 1/SEERee)) +
(HeatLoadElectricDRP x (3.412/HSPFbase – 3.412/HSPFee))
= (2000 x (0 – 1/20)) + (5000 x (3.412/3.412 – 3.412/12))
= 3,478 kWh
$\Delta kW_{SSP}$ = $BTUH_{Cool}$ x (1/EERbase - 1/EERee))/1,000 x CF
= (18,000 x (0 – 1/14)) / 1000) x 0.31
= - 0.40kW

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

ΔkWH = (CoolingLoadDHP x (1/SEERbase - 1/SEERee)) -
(HeatLoadGasDHP x 293.1 x 0.85 x (3.412/HSPFee))
= (4000 x (1/11 – 1/18)) - (40 x 293.3 x 0.85 x (3.412/11))
= -2,952 kWh (i.e. this results in an increase in electric consumption)
$\Delta kW_{SSP}$ = ($BTUH_{Cool}$ x (1/EERbase - 1/EERee))/1,000 x CF
= (30,000 x (1/9.96 – 1/13.5)) / 1000 x 0.31
= 0.24 kW (in the summer you see demand savings)
ΔMMBTU = HeatLoadGasReplaced / AFUEexist
= 40 / 0.80
= 50 MMBTU

Time of Sale / New Construction

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

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

$$\begin{aligned}
\Delta kWH &= (CoolingLoadDHP \times (1/SEERbase - 1/SEERee)) + (HeatLoadElectricDHP \times (3.412/HSPFbase - 3.412/HSPFee)) \\
&= (6000 \times (1/14 - 1/18)) + (12{,}000 \times (3.412/7.7 - 3.412/11)) \\
&= 1{,}634 kWh \\
\Delta kW_{SSP} &= (BTUH_{Cool} \times (1/EERbase - 1/EERee))/1{,}000 \times CF \\
&= (36{,}000 \times (1/11.8 - 1/13.5)) / 1000 \times 0.31 \\
&= 0.12 \text{ kW}
\end{aligned}$$

# High Efficiency Gas Boiler

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

### Measure Description

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

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

### Definition of Baseline Condition

The baseline condition is a boiler that meets the minimum Federal baseline AFUE for boilers. For boilers manufactured after September 2012, the Federal baseline is 82% AFUE[166].

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified combi-boiler with an AFUE rating ≥ 90% qualifying under ENERGY STAR Boiler Eligibility Criteria Version 3.0[167]

### Annual Energy Savings Algorithm

n/a

### Summer Coincident Peak kW Savings Algorithm

n/a

### Annual Fossil Fuel Savings Algorithm

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

*Where:*

*EFLHheat = Equivalent Full Load Heating Hours*

| *Location* | *EFLH* |
|---|---|
| *Wilmington, DE* | *848*[168] |

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[166] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32
[167] Energy Star Boiler Eligibility Criteria Version 3.0
[168] Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012

| | |
|---|---|
| *Baltimore, MD* | *620*[169] |
| *Washington, DC* | *528*[170] |

*BTUH* = *Input Capacity of Boiler*
= *Actual*

*AFUEbase* = *Efficiency in AFUE of baseline boiler*
= *82%*

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

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

ΔMMBTU = (620 * 100,000 * ((0.9/0.82) – 1)) /1,000,000
= 6.0 MMBTU

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 18 years[171].

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[169] 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.

[170] Full load heating hours derived by adjusting $FLH_{heat}$ for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

[171] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

# High Efficiency Furnace (gas) TOS

## Unique Measure Code: RS_HV_TOS_GASFUR_0415
## Effective Date: June 2015
## End Date: TBD

### Measure Description

This measure characterization provides savings for the purchase and installation of a new residential sized ENERGY STAR-qualified high efficiency gas-fired condensing furnace with a capacity of <225,000 Btu/h for residential space heating, instead of a new baseline gas furnace. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

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

### Definition of Baseline Condition

The baseline condition is a non-condensing gas furnace with an AFUE of 80%, or 81% if weatherized[172].

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified gas-fired condensing furnace with an AFUE rating ≥ 90%.[173]

### Annual Energy Savings Algorithm

n/a.

### Summer Coincident Peak kW Savings Algorithm

n/a

### Annual Fossil Fuel Savings Algorithm

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

*Where:*

*EFLHheat = Equivalent Full Load Heating Hours*

| Location | EFLH |
|---|---|
| *Wilmington, DE* | *848*[174] |
| *Baltimore, MD* | *620*[175] |

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[172] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32

[173] https://www.energystar.gov/products/heating_cooling/furnaces/key_product_criteria

[174] Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012

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

| | |
|---|---|
| *Washington, DC* | *528*[176] |

*BTUh* = *Input Capacity of Furnace*
= *Actual*

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

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

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

ΔMMBTU = 620 * 100,000 * (1/0.8 – 1/0.92) /1,000,000
= 10.1 MMBTU

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 18 years[177].

**Operation and Maintenance Impacts**

n/a

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[176] Full load heating hours derived by adjusting $FLH_{heat}$ for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

[177] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

# High Efficiency Furnace (gas) Early Replacement

**Unique Measure Code: RS_HV_ER_GASFUR_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure characterization savings for the early replacement of a new residential sized ENERGY STAR-qualified high efficiency gas-fired condensing furnace with a capacity of <225,000 Btu/h for residential space heating, instead of a new baseline gas furnace.

Early replacement occurs when the existing equipment is replaced with efficient equipment before its natural end of life. Savings are calculated between existing unit and efficient unit consumption during the assumed remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

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

### Definition of Baseline Condition

The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline for the remainder of the new, efficient equipment measure life.

If the existing equipment efficiency is unknown, use the prevailing federal efficiency standard based on age:

Baseline for furnaces based on manufacture date[178]:
Before November 19, 2015: 78 AFUE
November 19, 2015 or later: 80 AFUE, or 81 AFUE if weatherized

Note that to be characterized as early replacement, the age of the unit must not exceed the measure life of 18 years.

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified gas-fired condensing furnace with an AFUE rating ≥ 90%[179] and efficient fan motor. Note that efficient fan motors became federal baseline on furnaces manufactured on or after July 3, 2019[180]

### Annual Energy Savings Algorithm

Energy and demand savings result from a high efficiency brushless permanent magnet fan motor (BPM or ECM) installed with the new furnace. Efficient motor savings can only be claimed

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[178] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32
[179] https://www.energystar.gov/products/heating_cooling/furnaces/key_product_criteria
[180] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32

if the existing furnace does not have an efficient fan motor, and only until the end of the existing furnace remaining life.

Annual kWh savings is the sum of Heating, Cooling, and Circulation (ventilation only) mode savings for existing equipment remaining life and balance of new equipment life.

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

$\Delta kWh_{RL} = \Delta kWh\ heat$[181]

$\Delta kWh_{HEAT} = 168.9$[182]

Energy and demand savings for balance of new equipment life (12 years)

$\Delta kWh = 0$

$\Delta kW = 0$

**Summer Coincident Peak kW Savings Algorithm**

**N/A**

**Annual Fossil Fuel Savings Algorithm**

Savings for remaining life of existing unit life (6 years):

$$\Delta MMBTU_{RL} = (EFLH_{HEAT} * BTUh * ((AFUE_{EE}/AFUE_{EXIST}) - 1)) / 1{,}000{,}000$$

Savings for balance of new equipment life (12 years):

$$\Delta MMBTU_{BL} = (EFLH_{HEAT} * BTUh * ((AFUE_{EE} / AFUE_{BASE}) - 1))/1{,}000{,}000$$

*Where:*

$EFLH_{HEAT}$ = *Equivalent Full Load Heating Hours*

| Location | EFLHheat |
|---|---|
| Wilmington, DE | 848[183] |
| Baltimore, MD | 620[184] |

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[181] EmPOWER Maryland 2019-2020 Installation Year Deemed Savings Memo

[182] EmPOWER Maryland 2019-2020 Installation Year Deemed Savings Memo

[183] Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012

[184] 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.

| | |
|---|---|
| Washington, DC | 528[185] |

*BTUh* = *Input Capacity of furnace*
= *Actual*

$AFUE_{EXIST}$ = *Efficiency in AFUE of existing furnace*
= *Actual*
= *if unknown see guidance above in definition of baseline condition*

$AFUE_{EE}$ = *Efficiency in AFUE of efficient furnace*
= *Actual*

$AFUE_{BASE}$ = *Efficiency in AFUE of new baseline efficient Furnace*
= *.80 if non-weatherized*
= *.81 if weatherized*

**Illustrative Example** – do not use as default assumption
Installation of a 100,000 BTUh, 92% AFUE furnace in Maryland to replace a twelve year old furnace with an AFUE of .75 having the same capacity. There are six years remaining in the useful life of the existing furnace.

$\Delta kWh_{HEAT}$ = 168.9

$\Delta MMBTU_{RL}$ = (620 * 100,000 * ((1/0.92 / 1/0.75) – 1))/1,000,000
= 14.1 MMBTU

$\Delta MMBTU_{BL}$ = (620 * 100,000 * ((1/0.92 / 1/0.80) – 1))/1,000,000
= 9.3 MMBTU

**Annual Water Savings Algorithm**
n/a

**Measure Life**
The full measure life is assumed to be 18 years[186].
The RUL of existing equipment is assumed to be 6 years

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[185] Full load heating hours derived by adjusting $FLH_{heat}$ for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

[186] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.

# Smart Thermostat[*]

**Unique Measure Code: RS_HV_TOS_SMTHRM_0420, RS_HV_RF_SMTHRM_0420**
**Effective Date: April 2020**
**End Date: TBD**

## Measure Description

The Smart Thermostat measure involves the replacement of a manually operated or conventional programmable thermostat with a "smart" (advanced, wi-fi, or connected) thermostat as defined below. This measure applies to all residential applications and may be a time of sale or retrofit measure.

## Definition of Baseline Condition

This is defined as a retrofit measure. The baseline equipment is an assumed (defaulted) mix of manual and programmable thermostats.

## Definition of Efficient Condition

The efficient condition is a "smart" thermostat that has earned ENERGY STAR certification[187] and/or has the following product requirements[188]:

1. Automatic scheduling
2. Occupancy sensing (set "on" as a default)
3. For homes with a heat pump, smart thermostats must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.
4. Ability to adjust settings remotely via a smart phone or online the absence of connectivity to the connected thermostat (CT) service provider, retain the ability for residents to locally:
    a. view the room temperature,
    b. view and adjust the set temperature, and
    c. switch between off, heating and cooling.
5. Have a static temperature accuracy ≤ ± 2.0 °F
6. Have network standby average power consumption of ≤ 3.0 W average (Includes all equipment necessary to establish connectivity to the CT service provider's cloud, except those that can reasonably be expected to be present in the home, such as Wi-Fi routers and smart phones.)
7. Enter network standby after ≤ 5.0 minutes from user interaction (on device, remote or occupancy detection)
8. The following capabilities may be enabled through the CT device, CT service or any combination of the two. The CT product shall maintain these capabilities through subsequent firmware and software changes.
    a. Ability for consumers to set and modify a schedule.

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

[188] ENERGY STAR Smart Thermostat Specification, from which most requirements based: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0_0.pdf

b. Provision of feedback to occupants about the energy impact of their choice of settings.
c. Ability for consumers to access information relevant to their HVAC energy consumption, e.g. HVAC run time.

**Annual Energy Savings Algorithm**

Utilities offer smart thermostats through numerous channels, including retailers, HVAC contractors, QHEC (direct-install), new construction, and online stores. The level of HVAC system detail determines the most appropriate savings calculation method. Depending on the level of HVAC system information available, utilities should use one of three methods described below to calculate smart thermostat savings.

As the smart thermostat measure matures and utilities continue to collect information about the installation location and connected HVAC systems, the MD evaluation team will conduct analysis to update the savings estimates. The parameters and algorithms described in this section will be flagged for further revision in the future – they are not locked down for the duration of the cycle.

**<u>Method 1 (preferred)</u>**

The most accurate smart thermostat savings are calculated using recommended percent savings estimates with equipment-specific nameplate information or annual heating and cooling consumption. When heating and/or cooling consumption is known or has been estimated using a calibrated building simulation model,[189] utilities should use the following algorithms:

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

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

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

$$\mathbf{\Delta MMBTU} = Fuel\_Heating\_Saving\_\% \times Fuel\_Heating\_MMBTU$$

Where:

Elec_Heating_Saving_% = 6%
Cooling_Saving_% = 7%
Fuel_Heating_Saving_% = 6%[190]
Elec_Heating_kWh = Actual seasonal electric heat kWh consumption
Cooling_kWh = Actual seasonal cooling kWh consumption
Fuel_Heating_MMBTU = Actual seasonal fossil heating MMBTU consumption

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[189] For Residential New Construction, the use of building simulation results from a vetted tool (such as BEACON) that has not been directly calibrated to premise billing data is acceptable.

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

For New Construction applications assume that the heating and cooling % savings values are one half of those above.[191]

**Method 2**

Where actual heating or cooling energy consumption is not known but HVAC equipment characteristics are known, use the following algorithms:

Cooling Savings:

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

Electric Heat Savings:

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

Fossil heat Savings:

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

Where:

CCAP = Cooling capacity of existing AC unit, in kBTU/hr.
$\text{HCAP}_{\text{elec}}$ = Heating capacity of existing electric heat unit, in kBTU/hr.
$\text{HCAP}_{\text{fuel}}$ = Heating capacity of existing fossil heat unit, in MMBTU/hr.
SEER = SEER of controlled unit. If unknown use current energy code requirements for mechanical cooling efficiency (14 SEER). For GSHPs use EER.
HSPF = HSPF of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency (8.2). Electric strip heat HSPF = 3.412. For GSHPs use COP x 3.412.
AFUE = AFUE of controlled unit. If unknown use 82% for boiler, 80% for furnace.
$\text{EFLH}_{\text{cool}}$ = Full load hours for cooling equipment. See **Error! Reference source not found.**.
$\text{EFLH}_{\text{heat}}$ = Full load hours for heating equipment. See **Error! Reference source not found.***
*Use 620 $\text{EFLH}_{\text{heat}}$ for fossil fuel heating systems.

**Method 3**

If annual heating and cooling consumption and equipment characteristics are unknown, utilities should use the annual heating and cooling consumption values in **Error! Reference source not found.** with savings estimates (7% cooling, 6% heating) recommended above. For GSHPs with unknown equipment characteristics, utilities should use the ASHP values for an ASHP replacement.

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[191] Consensus judgement of the TRM Subcommittee, March 2020. Presumes a programmable thermostat baseline.

For smart thermostats installed with no other information available (e.g. upstream rebate) utilities should use the values in the column labeled "Unknown". If the HVAC system type is known but the system is not replaced, utilities should use the values in the column labeled "HVAC Unit Not Replaced" to estimate savings for smart thermostat measures. If a smart thermostat is installed with a new HVAC system, utilities should use the values in in the column labeled "HVAC Unit Replaced" to estimate savings.

**Annual Consumption Estimates**

| | **HVAC Replacement?** | **Unknown** | **HVAC Unit Not Replaced** | | **HVAC Unit Replaced** | |
|---|---|---|---|---|---|---|
| **State** | **HVAC Types** | **Mixed** | **CAC w/ Central Heating** | **ASHP** | **CAC w/ Central Heating** | **ASHP or GSHP** |
| **MD** | **Cooling (kWh)** | 2,105 | 1,774 | 2,435 | 1,148 | 1,576 |
| | **Heating (kWh)** | 2,296 | NA | 4,585 | NA | 3,282 |
| | **Heating (MMBTU)** | 30.9 | 62.0 | NA | 52.2 | NA |
| **DE** | **Cooling (kWh)** | 2,035 | 1,715 | 2,353 | 1,110 | 1,523 |
| | **Heating (kWh)** | 2,479 | NA | 4,950 | NA | 3,543 |
| | **Heating (MMBTU)** | 42.3 | 84.8 | NA | 71.4 | NA |
| **DC** | **Cooling (kWh)** | 2,645 | 2,229 | 3,060 | 1,442 | 1,980 |
| | **Heating (kWh)** | 2,179 | NA | 4,352 | NA | 3,115 |
| | **Heating (MMBTU)** | 26.4 | 52.8 | NA | 44.5 | NA |

### Demand Savings

The smart thermostat measure as defined here (i.e., without a corresponding demand reduction program) is assumed to have no demand savings. Smart thermostats with a demand response program added on top may generate significant demand savings, but those are not quantified as part of this measure.

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 7.5 years.[192]

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[192] Based on professional judgment of TRM technical team and stakeholder consensus. EULs observed include: 11 years in AR TRM and 10 years in IL TRM, both of which are based on programmable thermostat EULs. CA workpapers conclude 3-year EUL using persistence modeling. RTF concludes a 5-year EUL based on CA workpapers and concerns that there is little basis for assuming long-time persistence of savings, considering past challenges with manual overrides and "know-how" needed to use wifi-connected devices, including communicating hardware and software downloading. For discussion, see Northwest Regional Technical Forum January 2017. https://rtf.nwcouncil.org/measure/connected-thermostats
RTF_ResConnectedTstats_v1.1

# Room Air Conditioner, Early Replacement

**Unique Measure Code: RS_HV_EREP_RA/CES_0414**
**Effective Date: June 2014**
**End Date: TBD**

### Measure Description

This measure describes the early removal of an existing inefficient Room Air Conditioner unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. This measure is suitable for a Low Income or a Home Performance program.

Savings are calculated between the existing unit and the new efficient unit consumption during the assumed remaining life of the existing unit, and between a hypothetical new baseline unit and the efficient unit consumption for the remainder of the measure life.

### Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit for the remaining assumed useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard (i.e. with an efficiency rating of 10.9 CEER[193]).

### Definition of Efficient Condition

The efficient condition is a new replacement room air conditioning unit meeting the ENERGY STAR efficiency standard (i.e. with a CEER efficiency rating greater than or equal to 12.0[194]).

### Annual Energy Savings Algorithm

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

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

Savings for remaining measure life (next 9 years)

$$\Delta kWh = (Hours * BTUH * (1/CEERbase - 1/CEERee))/1{,}000$$

*Where:*

*Hours = Run hours of Window AC unit*
*= 325* [195]

*BTUh = Capacity of replaced unit*

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

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

[195] 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.

*= Actual or 8,500 if unknown* [196]
*EERexist = Efficiency of existing unit in BTUs per Watt-hour*
*= 9.8* [197]
*CEERbase = Efficiency of baseline unit in BTUs per Watt-hour*
*= 10.9* [198]
*CEERee = Efficiency of ENERGY STAR unit in BTUs per Watt-hour*
*= Actual or CEER 12 if unknown*

Illustrative example – do not use as default assumption
Replacing existing 8,500 BTUh Room AC unit with a new ENERGY STAR unit with CEER rating of 12:

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

ΔkWh = (325 * 8,500 * (1/9.8– 1/12)) / 1,000

= 52 kWh

Savings for remaining measure life (next 9 years)

ΔkWh = (325 * 8,500 * (1/10.9 – 1/12)) / 1,000

= 23 kWh

**Summer Coincident Peak kW Savings Algorithm**

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

ΔkW = ((BTUH * (1/EERexist - 1/CEERee))/1000) * CF

Savings for remaining measure life (next 9 years)

ΔkW = ((BTUH * (1/CEERbase - 1/CEERee))/1000) * CF

*Where:*

$CF_{SSP}$ *= Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
*= 0.31* [199]
$CF_{PJM}$ *= PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
*= 0.3*[200]

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

[197] Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.

[198] Minimum Federal Standard for capacity range.

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

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

Illustrative example – do not use as default assumption
Replacing existing 8,500 BTUh Room AC unit with a new ENERGY STAR unit with CEER rating of 12.0.

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

$\Delta kW_{SSP}$ = ((8,500 * (1/9.8 – 1/12)) / 1,000) * 0.31

= 0.0493 kW

Savings for remaining measure life (next 9 years)

$\Delta kW_{SSP}$ = ((8,500 * (1/10.9 – 1/12)) / 1,000) * 0.31

= 0.0222 kW

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 12 years[201]. Note this characterization also assumes there is 3 years of remaining useful life of the unit being replaced[202].

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[201] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.

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

# Room Air Conditioner, Early Retirement / Recycling

**Unique Measure Code: RS_HV_ERET_RA/C_0414**
**Effective Date: June 2014**
**End Date: TBD**

### Measure Description

This measure describes the savings resulting from implementing a drop off service taking existing working inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that a percentage of these units will ultimately be replaced with a baseline standard efficiency unit (note that if it is actually replaced by a new ENERGY STAR qualifying unit, the savings increment between baseline and ENERGY STAR should be captured under the ENERGY STAR Room AC Time of Sale measure).

### Definition of Baseline Condition

The baseline condition is the existing inefficient room air conditioning unit.

### Definition of Efficient Condition

Not applicable. This measure relates to the retiring of an existing inefficient unit. A percentage of units however are assumed to be replaced with a baseline new unit and the savings are therefore reduced to account for these replacement units.

### Annual Energy Savings Algorithm

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

*Where:*

*Hours = Run hours of Window AC unit*
*= 325* [203]
*BTU/hour = Capacity of replaced unit*
*= Actual or 8,500 if unknown* [204]
*EERexist = Efficiency of existing unit in BTUs per Watt-hour*
*= Actual or 9.8 if unknown* [205]
%replaced = Percentage of units dropped off that are replaced in the home
= 38%
CEERnewbase = *Efficiency of new baseline unit in BTUs per Watt-hour*

---

[203] 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.

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

[205] Minimum Federal Standard for most common room AC type (8000-14,999 capacity range with louvered sides) per federal standards from 10/1/2000 to 5/31/2014. Note that this value is the EER value, as CEER were introduced later.

$= 10.9$[206]

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

$$\Delta kWh = ((325 * 8{,}500 * (1/9.8))/1{,}000) - (0.38 * ((325 * 8{,}500 * (1/10.9))/1{,}000)$$

$$= 89 \text{ kWh}$$

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = [\ (BTUH * (1/EERexist)/1{,}000) - (\%replaced * BTUH * (1/CEERnewbase)/1{,}000)\ ] * CF$$

*Where:*

*$CF_{SSP}$ = Summer System Peak Coincidence Factor for Room A/C (hour ending 5pm on hottest summer weekday)*
*= 0.31* [207]

*$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Room A/C (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
*= 0.3*[208]

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

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

$$= 0.09 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 3 years[209].

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[206] Minimum Federal Standard for most common Room AC type – 8000-14,999 capacity range with louvered sides. Note that we assume the replacement is only at federal standard efficiency for the reason explained above. Current federal standards use CEER while previous federal standards used EER for efficiency levels.

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

[208] 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).

[209] 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

# Boiler Reset Controls

**Unique Measure Code: RS_HV_RF_BLRRES_0415**
**Effective Date:**
**End Date: TBD**

### Measure Description

This measure relates to improving system efficiency by adding controls to residential heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. The water can be run a little cooler during fall and spring, and a little hotter during the coldest parts of the winter. A boiler reset control has two temperature sensors - one outside the house and one in the boiler water. As the outdoor temperature goes up and down, the control adjusts the water temperature setting to the lowest setting that is meeting the house heating demand. There are also limits in the controls to keep a boiler from operating outside of its safe performance range.

### Definition of Baseline Condition

Existing condensing boiler in a single family residential setting without boiler reset controls.

### Definition of Efficient Condition

Natural gas single family residential customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse fashion with outdoor air temperature. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer's recommended minimum return temperature. This boiler reset measure is limited to existing condensing boilers serving a single family residence. Boiler reset controls for non-condensing boilers in single family residences should be implemented as a custom measure, and the cost-effectiveness should be confirmed.

### Annual Energy Savings Algorithm

n/a

### Summer Coincident Peak kW Savings Algorithm

n/a

### Annual Fossil Fuel Savings Algorithm

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

*Where:*

*Savings %* = *Estimated percent reduction in heating load due to boiler reset controls being installed*
*= 5%*[210]

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[210] Energy savings factor for residential applications taken from an article published by the Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. See: http://cleanboiler.org/learn-about/boiler-efficiency-improvement/efficiency-index/boiler-reset-control/

*EFLHheat* = *Equivalent Full Load Heating Hours*

| Location | EFLH |
|---|---|
| *Wilmington, DE* | *848*[211] |
| *Baltimore, MD* | *620*[212] |
| *Washington, DC* | *528*[213] |

*BTUH* = *Input Capacity of Boiler*
= *Actual*

Illustrative example – do not use as default
A boiler reset control is applied to a 80,000 BTUH boiler in Baltimore, MD.

ΔMMBTU = 0.05 * (620 * 80,000)/1,000,000

= 2.48 MMBTU

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The life of this measure is 15 years[214]

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[211] Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

[212] 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.

[213] Full load heating hours derived by adjusting $FLH_{heat}$ for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

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

# Ground Source Heat Pumps

### Unique Measure Code: RS_HV_TOS_GSHPS_0420, RS_HV_NC_GSHPS_0420

### Effective Date: April 2020
### End Date: TBD

**Measure Description**

This measure characterizes the installation of an ENERGY STAR qualified Ground Source Heat Pump (GSHP) either during new construction or at Time of Sale/Replacement of an existing system(s). The baseline is always assumed to be a new baseline Air Source Heat Pump. Savings are calculated due to the GSHP providing heating and cooling more efficiently than a baseline ASHP, and where a desuperheater is installed, additional Domestic Hot Water (DHW) savings occur due to displacing existing water heating.

The ENERGY STAR efficiency standards are presented below.

ENERGY STAR Requirements (Effective January 1, 2012)

| Product Type | Cooling EER | Heating COP |
|---|---|---|
| Water-to-air | | |
| Closed Loop | 17.1 | 3.6 |
| Open Loop | 21.1 | 4.1 |
| Water-to-Water | | |
| Closed Loop | 16.1 | 3.1 |
| Open Loop | 20.1 | 3.5 |
| Direct Geoexchange[215] | 16 | 3.6 |

Evaluators should be aware that there will be an interaction between this measure and others, e.g. duct sealing, air sealing and insulation measures. Comprehensive building efficiency improvements will reduce load and may lead to downsizing of space conditioning equipment. To properly account for these interactive effects, energy modeling should be performed and those results should be used for savings attribution in place of savings algorithms shown here. Effects of HVAC downsizing can be attributed to either weatherization or HVAC, but not both.

**Definition of Baseline Condition**

New Construction:

The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8[216] EER. If a desuperheater is installed, the

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[215] Direct GeoExchange (DGX) is defined by Energy Star as: "A geothermal heat pump model in which the refrigerant is circulated in pipes buried in the ground or submerged in water that exchanges heat with the ground, rather than using a secondary heat transfer fluid, such as water or antifreeze solution in a separate closed loop." See https://www.energystar.gov/products/heating_cooling/heat_pumps_geothermal/key_product_criteria.

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

baseline for DHW savings is assumed to be a Federal Standard electric hot water heater, with Energy Factor calculated as follows[217]:

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

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

Time of Sale:
The baseline equipment is assumed to be an Air Source Heat Pump meeting the Federal Standard efficiency level; 14 SEER, 8.2 HSPF and 11.8 EER. If a desuperheater is installed, the baseline for DHW savings is assumed to be the existing home's hot water heater fuel and efficiency.

If electric DHW, and unknown efficiency – assume efficiency is equal to pre 4/2015 Federal Standard:

EF = 0.93 – (0.00132 x rated volume in gallons)[218]
If size is unknown, assume 50 gallons; 0.864 EF

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

EF = (0.67 – 0.0019 x rated volume in gallons)[219].
If size is unknown, assume 40 gallons; 0.594 EF

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

**Definition of Efficient Condition**

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

**Annual Energy Savings Algorithm**

$\Delta kWh$ = [Cooling savings] + [Heating savings] + [DHW savings]
= [(FLHcool x BTUc x $(1/SEER_{base}$– $(1/EER_{PL})/1000]$ +
[FLHheat x BTUh x $(1/HSPF_{base}$ – $(1/(COP_{PL}$ x 3.412)))/1000] + [ElecDHW x %DHWDisplaced x $(((1/EF_{ELEC})$ x GPD x Household x 365.25 x γWater x $(T_{OUT} – T_{IN})$ x 1.0) / 3412)]

*Where:*

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

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

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

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

| *Location* | *Run Hours* |
|---|---|
| *Wilmington, DE* | *524* [220] |
| *Baltimore, MD* | *542* [221] |
| *Washington, DC* | *681* |

**BTUc** = High-stage cooling capacity Btu/h. If capacity not provided in BTUs, utilities should estimate using nameplate tons: **tons** x **12,000 Btu/h per ton**.

**$BTU_H$** = High-Stage heating capacity Btu/h. If capacity not provided in BTUs, utilities should estimate using nameplate tons: **tons** x **12,000 Btu/h per ton**.

*SEERbase* = *SEER Efficiency of new replacement baseline unit*
= *14*[222]

*$EER_{FL}$* = *Full Load EER Efficiency of efficient GSHP unit*[223]
= *Actual installed*

*FLHheat* = *Full load heating hours*

| *Location* | *EFLH* |
|---|---|
| *Wilmington, DE* | *848*[224] |
| *Baltimore, MD* | *620*[225] |
| *Washington, DC* | *528*[226] |

*$HSPF_{base}$* =*Heating System Performance Factor of new replacement baseline heating system (kBTU/kWh)*
=*8.2* [227]

*$COP_{FL}$* = *Full Load Coefficient of Performance of efficient unit*[228]
= *Actual Installed*

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

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

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

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

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

[224] Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012; http://www.dnrec.delaware.gov/energy/information/otherinfo/Documents/EM-and-V-guidance-documents/DELAWARE_TRM_August%202012.pdf

[225] 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.

[226] Full load heating hours derived by adjusting $FLH_{heat}$ for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

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

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

*ElecDHW* = 1 if existing DHW is electrically heated
= 0 if existing DHW is not electrically heated
*%DHWDisplaced* = Percentage of total DHW load that the GSHP will provide
= Actual if known
= If unknown and if desuperheater installed assume 44%[229]
= 0% if no desuperheater installed
$EF_{ELEC}$ = Energy Factor (efficiency) of electric water heater
*For new construction assume federal standard*[230]*:*
For <=55 gallons: 0.96 – (0.0003 x rated volume in gallons)
For >55 gallons: 2.057 – (0.00113 x rated volume in gallons)
If size is unknown, assume 50 gallon; 0.945 EF.

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

*EF* = 0.93 – (0.00132 x rated volume in gallons)[231]
If size is unknown, assume 50 gallon; 0.864 EF

*GPD* = Gallons Per Day of hot water use per person
= 45.5 gallons hot water per day per household/2.59 people per household[232]
= 17.6

*Household* = Average number of people per household

= 2.53 [233]
*365.25* = Days per year
$\gamma$*Water* = Specific weight of water
= 8.33 pounds per gallon
$T_{OUT}$ = Tank temperature
= 125°F
$T_{IN}$ = Incoming water temperature from well or municipal system
= 60.9 [234]
*1.0* = Heat Capacity of water (1 BTU/lbx°F)
*3412* = Conversion from BTU to kWh

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

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

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

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

[233] US Energy Information Administration, Residential Energy Consumption Survey 2009; http://www.eia.gov/consumption/residential/data/2009/xls/HC9.10%20Household%20Demographics%20in%20South%20Region.xls

[234] Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs." April 4, 2014, Appendix E, page 66.

Illustrative Example – do not use as default assumption

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

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

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

= 367 + 1235 + 1185

= 2787 kWh

**Summer and Winter PJM Coincident Peak kW Savings Algorithm**

$$\Delta kW_{PJM\ summer} = \frac{BTU_c}{1{,}000\,\frac{BTU}{kBTU}} \times \left(\frac{1}{EER_{baseline}} - \frac{1}{EER_{ee}}\right) \times CF_{adj}$$

$$\Delta kW_{PJM\ winter} = \frac{BTU_h}{1{,}000\,\frac{BTU}{kBTU}} \times \left(\frac{1}{HSPF_{baseline}} - \frac{1}{COP_{ee*} \times 3.412}\right) \times CF_{adj}$$

The table below lists the CF adjustment factors that Maryland utilities should use to calculate winter and summer PJM peak demand savings by for the different measure categories. Parameters in the table below replace the peak coincidence factor (CF$_{ssp}$ = 0.66) in the previous TRM's demand savings algorithm. The new summer and winter parameters (adjusted CF values, CF$_{adj}$) are unique to each utility and measure category. These enable the calculation of PJM peak demand savings using the standard algorithm and the rated efficiency and capacity values reported in utility's tracking databases. The algorithms in the equations above and the adjustment factors (CF$_{adj}$) replace the ΔkW/ton method used to calculate utility demand savings. Note GSHPs use coefficient of performance (COP) to describe heating efficiency. The HSPF value in the equation above may be estimated for GSHPs by assuming COP x 3.412 = HSPF.

**Table 3. Factors (CF$_{adj}$) for Summer and Winter Demand Savings Algorithm**

| Utility | ASHP SEER 16 | ASHP SEER 16 Winter | ASHP SEER 18 | ASHP SEER 18 Winter | CAC SEER 16 | CAC SEER 18 | GSHP | GSHP Winter |
|---|---|---|---|---|---|---|---|---|
| BGE | 1.09 | 0.73 | 1.08 | 0.55 | 0.84 | 0.81 | 0.59 | 0.53 |
| DPL | 0.69 | 0.53 | 0.93 | 0.29 | 0.68 | 0.84 | 0.59 | 0.55 |
| Pepco | 0.98 | 0.94 | 1.31 | 0.60 | 0.94 | 0.91 | 0.61 | 0.62 |
| SMECO | 1.15 | 0.89 | 1.22 | 0.62 | 0.81 | 1.05 | 0.62 | 0.73 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PE | 0.86 | 0.87 | 1.09 | 0.71 | 0.64 | 0.76 | 0.56 | 0.55 |

*Where:*

*EERbaseline = Energy Efficiency Ratio Efficiency of baseline unit*
*= 11.8*
*EERee = EER Efficiency of existing unit*
*= Actual EER of unit should be used*
*EERee = Energy Efficiency Ratio Efficiency of ENERGY STAR unit*
*= Actual installed*
*$CF_{adj}$ = Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday) see table.*

Illustrative example – do not use as default assumption.

Time of Sale example: a 3-ton unit with efficient EER rating of 12.5 upgraded from lower efficiency to higher, with same size unit:

$$\Delta kW_{SSP} = ((36000 \times 1/11.8) - (36000 \times 1/12.5)) / 1000 \times 0.69$$

$$= 0.12 \text{ kW}$$

$$\Delta kW_{PJM} = ((36000 \times 1/11.8) - (36000 \times 1/12.5)) / 1000 \times 0.66$$

$$= 0.11 \text{ kW}$$

Early Replacement example where there is a “right-sizing” adjustment allowing for a lesser capacity system (note that the algorithm is the same regardless of pre/post capacity): an existing 3-ton unit with EER 9.9 is replaced by a 2-ton unit with EER rating of 12.5 in Baltimore:

ΔkW for remaining life of existing unit:

$$\Delta kW_{SSP} = ((36000 \times 1/9.9) - (24000 \times 1/12.5)) / 1000 \times 0.69$$

$$= 1.18 \text{ kW}$$

$$\Delta kW_{PJM} = ((36000 \times 1/9.9) - (24000 \times 1/12.5)) / 1000 \times 0.66$$

$$= 0.1.13 \text{ kW}$$

ΔkW for remaining measure life:

$$\Delta kW_{SSP} = ((36000 \times 1/11.8) - (24000 \times 1/12.5)) / 1000 \times 0.69$$

$$= 0.78 \text{ kW}$$

$$\Delta kW_{PJM} ((36000 \times 1/11.8) - (24000 \times 1/12.5)) / 1000 \times 0.66$$

$$= 0.75 \text{ kW}$$

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*EERbase* = *EER Efficiency of new replacement unit*
= *11.8*[235]

*$EER_{FL}$* = *Full Load EER Efficiency of ENERGY STAR GSHP unit* [236]
= *Actual*

*$CF_{SSP}$* = *Summer System Peak Coincidence Factor for Central A/C (hour ending 5pm on hottest summer weekday)*
= *0.69* [237]

*$CF_{PJM}$* = *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* [238]

Illustrative Example– do not use as default assumption

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

$\Delta kW_{SSP}$ = ((36,000 x (1/11.8 – 1/19))/1000) x 0.69
= 0.80 kW

$\Delta kW_{PJM}$ = ((36,000 x (1/11 – 1/19))/1000) x 0.66
= 0.76 kW

**Annual Fossil Fuel Savings Algorithm**

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

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

*Where:*

*$EF_{GAS\ EXIST}$* = *Energy Factor (efficiency) of existing gas water heater*
= *Actual. If unknown assume efficiency is equal to pre 4/2015 Federal Standard:*
= *(0.67 – 0.0019 x rated volume in gallons)*[239].
*If size is unknown, assume 40 gallons; 0.594 EF*

*All other variables provided above*

---

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

[236] As per conversations with David Buss territory manager for Connor Co, the EER rating of an ASHP equate most appropriately with the full load EER of a GSHP.

[237] 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.

[238] 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.

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

Illustrative Example – do not use as default assumption

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

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

= [(1 – 0) x 0.44 x (((1/0.594) x 17.6 x 2.53 x 365.25 x 8.33 x (125 - 60.9) x 1)/1,000,000)]

= 6.4 MMBTU

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 20 years[240].

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[240] The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007.
http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.

# High Efficiency Bathroom Exhaust Fan

**Unique Measure Code(s): RS_HV_TOS_BTHFAN_0415**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 20 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

### Definition of Baseline Condition

New standard efficiency (average CFM/Watt of 3.1[241]) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2[242].

### Definition of Efficient Condition

New efficient (average CFM/watt of 8.3[243]) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate (20 CFM) indicated by ASHRAE 62.2[244]

### Annual Energy Savings Algorithm

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

*Where:*

*CFM* = *Nominal Capacity of the exhaust fan*
= *20 CFM*[245]
*ηBaseline* = *Average efficacy for baseline fan*
= *3.1 CFM/Watt*[246]
*ηEffcient* = *Average efficacy for efficient fan*

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[241] VEIC analysis looking at average baseline fan (i.e. non-Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

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

[243] VEIC analysis looking at average efficient fan (i.e. Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

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

[245] 20 CFM is used with continuous bathroom ventilation in ASHRAE 62.2. Note that 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

[246] VEIC analysis looking at average baseline fan (i.e. non-Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

*= 8.3 CFM/Watt*[247]

*Hours* *= assumed annual run hours,*
*= 8760 for continuous ventilation.*

ΔkWh = (20 * (1/3.1 – 1/8.3)/1000) * 8760
= 35.4 kWh

**Summer Coincident Peak kW Savings Algorithm**

ΔkW = (CFM * (1/ηBaseline - 1/ηEfficient)/1000) * CF

*Where:*

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

*Other variables as defined above*

ΔkW = (20 * (1/3.1 – 1/8.3)/1000) * 1.0
= 0.0040 kW

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 19 years[248].

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[247] VEIC analysis looking at average efficient fan (i.e. Brushless Permanent Magnet) efficacies at static pressures of 0.1 and 0.25 inches of water column for quiet fans rated for 50 CFM.

[248] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans. http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.

# ENERGY STAR Ceiling Fan

**Unique Measure Code: RS_HV_TOS_ESCFN_0415, RS_HV_NC_ESCFN_0415**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

A ceiling fan/light unit meeting the ENERGY STAR efficiency specifications is installed in place of a model meeting the federal standard. ENERGY STAR qualified ceiling fan/light combination units are over 60% more efficient than conventional fan/light units, and use improved motors and blade designs[249].

Due to the savings from this measure being derived from more efficient ventilation and more efficient lighting, and the loadshape and measure life for each component being very different, the savings are split in to the component parts and should be claimed together. Lighting savings should be estimated utilizing the ENERGY STAR Integrated Screw Based SSL screw-in measure.

### Definition of Baseline Equipment

The baseline equipment is assumed to be a standard fan with EISA qualified incandescent or halogen light bulbs.

### Definition of Efficient Equipment

The efficient equipment is defined as an ENERGY STAR certified ceiling fan with integral LED bulbs.

### Annual Energy Savings Algorithm

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

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

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

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

*Where*[250]*:*

*Days = Days used per year*

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[249] http://www.energystar.gov/products/certified-products/detail/ceiling-fans

[249] All fan default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan

Savings Calculator;
http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?8178-e52c

*= Actual. If unknown use 365.25 days/year*

*FanHours = Daily Fan "On Hours"*
*= Actual. If unknown use 3 hours*

*$\%Low_{base}$ = Percent of time spent at Low speed of baseline*
*= 40%*

*$WattsLow_{base}$ = Fan wattage at Low speed of baseline*
*= Actual. If unknown use 15 watts*

*$\%Med_{base}$ = Percent of time spent at Medium speed of baseline*
*= 40%*

*$WattsMed_{base}$ = Fan wattage at Medium speed of baseline*
*= Actual. If unknown use 34 watts*

*$\%High_{base}$ = Percent of time spent at High speed of baseline*
*= 20%*

*$WattsHigh_{base}$ = Fan wattage at High speed of baseline*
*= Actual. If unknown use 67 watts*

*%LowES = Percent of time spent at Low speed of ENERGY STAR*
*= 40%*

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

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

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

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

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

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

| | *Low Speed* | *Medium Speed* | *High Speed* |
|---|---|---|---|
| *Percent of Time at Given Speed* | *40%* | *40%* | *20%* |
| *Conventional Unit Wattage* | *15* | *34* | *67* |
| *ENERGY STAR Unit Wattage* | *6* | *23* | *56* |
| *ΔW* | *9* | *11* | *11* |

*If the lighting WattsBase and WattsEE is unknown, assume the following*

*WattsBase = 3 x 43 = 129 W*

*WattsEE = 1 x 42 = 42 W*

Deemed savings if using defaults provided above:

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

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

$\Delta kWh$ = 11.2 + 77.3

= 88.5 kWh

**Summer Coincident Peak kW Savings Algorithm**

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

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

$\Delta kW_{Light}$ = ((WattsBase - WattsEE) /1000) * ISR * WHFd * CFlight

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

*Where:*

*CFfan$_{SSP}$ = Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
*= 0.31* [251]

*CFfan$_{PJM}$ = PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
*= 0.3*[252]

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

[252] Assuming that the CF for a ceiling fan is the same as Room AC; Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf).

*CFlight = Summer Peak coincidence factor for lighting savings*

| Installation Location | Type | Coincidence Factor CF |
|---|---|---|
| Residential interior and in-unit Multi Family | Utility Peak CF | 0.082[253] |
| | PJM CF | 0.084[254] |

Deemed savings if using defaults provided above:

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

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

$\Delta kW_{ssp}$ = 0.0034 + 0.0083
= 0.012 kW

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

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

$\Delta kW_{pjm}$ = 0.0033 + 0.0086
= 0.012 kW

**Annual Fossil Fuel Savings Algorithm**

Heating penalty from improved lighting:

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

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

Deemed savings if using defaults provided above:

ΔMMBTUPenalty = - ((((129 – 42) / 1000) * 1.0 * 898 * 0.47 * 0.003412) / 0.84) * 0.625

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[253] Based on EmPOWER_EY5 Deemed Savings Recommendations_20Jan2015 DRAFT.

[254] Ibid.

$$= -0.09$$

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 15 years.

# Residential Gas Combination (“Combi”) Boiler

**Unique Measure Code: RS_HV_TOS_GASCOMB_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure characterizes costs and savings associated with the purchase and installation of a new ENERGY STAR-qualified residential boiler, which also provides hot water for domestic use. Such boilers are considered residential gas-fired combination boilers (“combi-boilers”). Eligibility requirements for this measure are aligned with ENERGY STAR qualification criteria[255]. The combi-boiler must 1) be a self-contained fuel-burning appliance; 2) have an input less than 300,000 Btu/hr; 3) operate at or below 160 psig water pressure and 250°F water temperature; 4) supply low-pressure steam or hot water for space heating applications; and 5) provides hot water for domestic or other use.

### Definition of Baseline Condition

There are two baseline conditions referenced in this measure:

1. Space heating. The baseline condition is a residential gas boiler that meets the minimum Federal standard for gas-fired hot water boilers manufactured after September 1, 2012 of **82% AFUE**[256].
2. Water heating. The baseline condition is a residential domestic hot water heater that meets the minimum Federal standard for water heaters[257]. The baseline UEF values are provided in the table below, “Efficiency Criteria Table; Consumer Gas Water Heaters”.

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR-qualified[255] combi-boiler with an AFUE ≥90%, and a UEF value no less than the appropriate “Efficient” condition provided in the table below.

| **Efficiency Criteria Table; Consumer Gas Water Heaters** | | | | | |
|---|---|---|---|---|---|
| Min Uniform Energy Factor (UEF) - based on size and draw pattern | | | | | |
| **Condition** | Size (Vs) | *very small 10GPD* | *low 38GPD* | *medium 55GPD* | *high 84GPD* |
| Base | ≥20 and ≤55 gal | 0.3456 – (0.0020 × Vs) | 0.5982 – (0.0019 × Vs) | 0.6483 – (0.0017 × Vs) | 0.6920 – (0.0013 × Vs) |
| | >55 gal and ≤100 gal | 0.6470 – (0.0006 × Vs) | 0.7689 – (0.0005 × Vs) | 0.7897 – (0.0004 × Vs) | 0.8072 – (0.0003 × Vs) |
| | instantaneous gas <2 gal | 0.80 | 0.81 | 0.81 | 0.81 |
| Efficient | ≤55 gal | NA | NA | 0.64 | 0.68 |
| | >55 gal | NA | NA | 0.78 | 0.80 |

---

[255] Energy Star boilers key product criteria
[256] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32(e)(2)(ii)
[257] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32(d)

| | | | | | |
|---|---|---|---|---|---|
| | instantaneous gas <2 gal | 0.87 | 0.87 | 0.87 | 0.87 |

Example calculation of baseline UEF for a 40 gallon water heater with a medium draw pattern:

$$\begin{aligned} UEF &= 0.6483 - (0.0017 * Vs) \\ &= 0.6483 - (0.0017 * 40) \\ &= 0.58 \end{aligned}$$

**Determining Draw Pattern**

The relevant hot water draw pattern is specific to usage at the installed location. If actual draw pattern is not known, it can be estimated from the water heater's first hour rating[258] per table below. If first hour rating is unknown, use medium draw pattern with rated storage capacity ≤50 gallons, and high draw pattern if >50 gallons.[259]

| Draw Pattern based on First Hour Rating | |
|---|---|
| **First Hour Rating** | **Draw Pattern** |
| <18 gallons | Very Small |
| ≥18 and <51 gallons | Low |
| ≥51 and <75 gallons | Medium |
| ≥75 gallons | High |

**Annual Energy Savings Algorithm**

**n/a**

**Summer Coincident Peak kW Savings Algorithm**

**n/a**

**Annual Fossil Fuel Savings Algorithm**

$$\Delta MMBTU = \Delta MMBTUdhw + \Delta MMBTUheat$$

$$\Delta MMBTUdhw = (1-(UEFbase / UEFefficient))* (GPD * Household * 365 * \gamma Water * (TOUT - Tin) *1.0 ) / 1{,}000{,}000$$

*Where:*

$UEF_{BASE}$ = *Uniform Energy Factor (efficiency) of standard efficiency gas water heater based on minimum federal standards, per Efficiency Criteria Table.*

$UEF_{EFFICIENT}$ = *Uniform Energy Factor of efficient, installed water heater*

---

[258] CFR part 430 App E 5.4.1

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

*= Actual*
*= AFUE if UEF is not separately specified use AFUE 9*9*

*GPD = Gallons Per Day of hot water use per person*
*= 45.5 gallons hot water per day per household/2.53people per household*[260]
*= 17.6*

*Household = Average number of people per household*
*= 2.53*

*365 = Days per year, on average*

*γWater = Specific Weight of water*
*= 8.33 pounds per gallon*

*Tout = Tank temperature*
*= 125°F*

*Tin = Incoming water temperature from well or municipal system*
*= 60.9*

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

ΔMMBTUheat =

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

*Where:*

*EFLHheat = Equivalent Full Load Heating Hours*

| *Location* | *EFLH* |
|---|---|
| Wilmington, DE | 848[261] |
| Baltimore, MD | 620[262] |
| Washington, DC | 528[263] |

*BTUh = Input Capacity of Boiler*
*= Actual*

*AFUEbase = Efficiency in AFUE of baseline boiler*

---

[260] US Energy Information Administration, Residential Energy Consumption Survey 2009; http://www.eia.gov/consumption/residential/data/2009/xls/HC9.10%20Household%20Demographics%20in%20South%20Region.xls

[261] Based on simulation model as described in ODC Delaware Technical Resource Manual, April 30, 2012

[262] 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.

[263] Full load heating hours derived by adjusting $FLH_{heat}$ for Baltimore, MD based on Washington, DC HDD base 60°F: 620 *2957/3457 = 528 hours.

*= 82%*

*AFUEee* *= Efficiency in AFUE of new, efficient combi-boiler*

**Illustrative example** – do not use as default assumption
The purchase and installation of a 199,000 BTUh, 92% AFUE combi-boiler in Baltimore, MD:

ΔMMBTUdhw
= 1 – (.58 / .92) * (17.6 * 2.53 * 365 * 8.33 * (125 – 60.9) * 1.0 ) / 1,000,000
= (.369) * (135,478 * (65) *1) / 1,000,000
= 3.21 MMBTU

ΔMMBTUheat =
ΔMMBTU = EFLHheat * BTUh * ((AFUEee/AFUEbase) – 1) /1,000,000
= 620 * 199,000 * ((.92 / 0.8) – 1) /1,000,000
= 18.5 MMBTU

Total savings = 3.21 + 18.5 = 21.71MMBTU/year

**Annual Water Savings Algorithm**
n/a

**Measure Life**
The measure life is assumed to be 20 years.
various sources referencing DEER2014. NG boiler and NG instantaneous DHW, both 20 yrs

*Domestic Hot Water (DHW) End Use*

# Faucet Aerators

**Unique Measure Code(s): RS_WT_DI_FAUCET_0420 and RS_WT_TOS_FAUCET_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a low flow (≤1.5 GPM) faucet aerator in a home. This could be a retrofit direct install measure or a new installation.

### Definition of Baseline Condition

The baseline is a standard faucet aerator using 2.2 GPM. For direct install programs, utilities may choose to measure the actual flow rate of the existing aerator and use that in the algorithm below

### Definition of Efficient Condition

The efficient condition is an energy efficient faucet aerator using rated GPM of the installed aerator. If actual flow rates of the baseline fixtures are used in a direct install program, then the actual flow rate of the installed aerators should be used as well.

### Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta kWH^{264} = (((GPM_{base} \text{ x } Throttle_{base}) - (GPM_{low} \text{ x } Throttle_{low})) \text{ x } Time_{faucet} \text{ x } \#people \text{ x } days/year \text{ x } DR) \text{ x } 8.3 \text{ x } 1.0 \text{ x } (Temp_{ft} - Temp_{in}) / DHW\ Recovery\ Efficiency / 3{,}412$$

*Where:*

*GPMbase = Gallons Per Minute of baseline faucet*
*= 2.2* [265] *or actual flow rate if recorded*
*GPMlow = Gallons Per Minute of low flow faucet*
*= Rated flow rate of unit installed or actual flow rate if baseline flow rate used.*
*# people = Average number of people per household*
= 2.39 [266]

---

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

[265] 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.

[266] This is the average from three separate sources: the Mid-Atlantic TRM V7, Pennsylvania TRM, and Wisconsin Focus on Energy TRM.

$Time_{faucet}$ = *Average minutes of use per person per fixture per day. 4.5 minutes for kitchens and 1.6 minutes for bathrooms*[267]
*= 2.42 if unknown*[268]
*days/y* = *Days faucet used per year = 365*
*DR* = *Percentage of water flowing down drain (if water is collected in a sink, a faucet aerator will not result in any saved water)*
*= 50% for kitchens, 70% for bathrooms*
$Throttle_{base}$ = *83%*[269]
$Throttle_{low}$ = *95%*[270]
*8.3* = *Constant to convert gallons to lbs*
*1.0* = *Heat Capacity of water (BTU/lb-°F)*

$TEMP_{ft}$ = *Assumed temperature of water used by faucet*
*= 93 kitchen, 86 bathrooms*
$TEMP_{in}$ = *Assumed temperature of water entering house*
*= 60.9* [271]
*DHW Recovery Efficiency* = *Recovery efficiency of electric water heater*
*= 0.98* [272]
*3,412* = *Constant BTU per kWh*

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator in a kitchen installed through the QHEC program:

$$\Delta kWH = (((2.2 \times 0.83) - (1.5 \times 0.95)) \times 4.5 \times 2.39 \times 365 \times 0.5) \times 8.3 \times 1.0 \times (93 - 60.9) / 0.98 / 3{,}412$$

$$= 62.7\ kWh$$

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

**Summer Coincident Peak kW Savings Algorithm**

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

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator in a kitchen installed through the QHEC program:

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

[268] Total usage divided by faucets per home assuming 1 kitchen faucet and 2.52 bathroom faucets on average: (4.5 + 2.52*1.6)/3.52 = 2.42

[269] Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[270] Ibid.

271 Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

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

*Hours* = *Average number of hours per year spent using faucet*

= $\#people \times Time_{faucet} / 60 * 365$

= $2.39 \times 4.5 / 60 * 365$

= $65.4$

*CF* = *Summer Peak Coincidence Factor for measure*

= 0.00262 [273]

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

$\Delta kW = 62.7 / 65.4 * 0.00262$

$= 0.0025$ kW

**Annual Fossil Fuel Savings Algorithm**

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

$$\Delta MMBTU = (((GPM_{base} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Time_{faucet} \times \#people \times days/year \times DR) \times 8.3 \times 1.0 \times (Temp_{ft} - Temp_{in}) / (DHW\ Recovery\ Efficiency) / 10^6$$

*Where:*

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

= 0.80 [274]

*All other variables* *As above*

Illustrative example – do not use as default assumption
For a 1.5 GPM rated aerator in a kitchen installed through the QHEC program:

$$\Delta MMBTU = (((2.2 \times 0.83) - (1.5 \times 0.95)) \times 4.5 \times 2.39 \times 365 \times 0.5) \times 8.3 \times 1.0 \times (93 - 60.9) / 0.8 / 10^6$$

$$= 0.262 \text{ MMBTU}$$

**Annual Water Savings Algorithm**

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

*Where:*

*748* = *Constant to convert from gallons to CCF*

*All other variables* *As above*

---

[273] 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

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

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

$$\text{Water Savings} = ((2.2 \times 0.83) - (1.5 \times 0.95)) \times 4.5 \times 2.39 \times 365 \times 0.5 / 748$$

$$= 1.052 \text{ CCF}$$

kWh Savings from Water Reduction

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

$\Delta$kWhwater[275] $= 2.07$ kWh/CCF * $\Delta$Water (CCF)

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

$$\Delta kWh_{water} = 2.07 \text{ kWh/CCF} * 1.052 \text{ CCF}$$
$$= 2.18 \text{ kWh}$$

**Measure Life**

The measure life is assumed to be 10 years.[276]

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[275] This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

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

# Low Flow Shower Head

**Unique Measure Code(s): RS_WT_DI_SHWRHD_0420, RS_WT_TOS_SHWRHD_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a low flow (≤2.0 GPM) showerhead in a home. This is a retrofit direct install measure or a new installation.

### Definition of Baseline Condition

The baseline is a standard showerhead using 2.5 GPM. For direct install programs, utilities may choose to measure the actual flow rate of the existing showerhead and use that in the algorithm below

### Definition of Efficient Condition

The efficient condition is an energy efficient shower head with a lower GPM flow than required by code. If baseline flow is not measured in the program, then the rated flow can be used for the efficient condition. However, if actual measured flow rates of the baseline fixtures are used in a direct install program, then the actual measured flow rate of the installed efficient aerators should be used as well.

### Annual Energy Savings Algorithm

If electric domestic water heater:

$$\Delta kWH^{277} = ((GPMbase - GPMlow) \times Time_{shower} \times \#\ people \times Showers_{Person} \times days/year / ShowerHeads/home) \times 8.3 \times 1.0 \times (TEMPsh - TEMPin) / DHW\ Recovery\ Efficiency / 3{,}412$$

*Where:*

*GPMbase* = *Gallons Per Minute of baseline showerhead*
= *2.5* [278] *or actual flow rate if recorded*
*GPMlow* = *Gallons Per Minute of low flow showerhead*
= *Rated flow rate of unit installed or actual flow rate if baseline flow rate used.*
*# people* = *Number of people per household, if unknown, use* 2.39[279].
$Time_{Shower}$ = *7.8 minutes*[280]

---

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

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

[279] This is the average from three separate sources: the Mid-Atlantic TRM V7, Pennsylvania TRM, and Wisconsin Focus on Energy TRM.

280 Table 6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. The study compared shower length by single-family and multifamily

*$Showers_{Person}$* = *Average showers per person per day*
*=0.6*[281]

*days/year* = *Days shower used per year*
*= 365*

*ShowerHeads/home* = *Average number of showers in the home*
*= 1.56 for QHEC and 2.46 for HPwES. This is the result of EY3 verification surveys. 1.6 for all other channels*[282]

*8.3* = *Constant to convert gallons to lbs*

*1.0* = *Specific heat capacity of water (BTU/lb-°F)*

*TEMPsh* = *Assumed temperature of water used for shower*
*= 105* [283]

*TEMPin* = *Assumed temperature of water entering house*
*= 60.9* [284]

*DHW Recovery Efficiency* = *Recovery efficiency of electric water heater*
*= 0.98* [285]

*3,412* = *Constant BTU per kWh*

Illustrative example – do not use as default assumption
For a 1.5 GPM rated showerhead installed through the QHEC program:

$$\Delta kWH = ((2.5 – 1.5) \times 7.8 \times 2.39 \times 0.6 \times 365 / 1.56) \times 8.3 \times 1.0 \times (105 - 60.9) / .98 / 3412$$

$$= 5286 \text{ kWh}$$

---

populations, finding no statistical difference in showering times. For the energy-saving analysis, the study used the combined single-family and multifamily average shower length of 7.8 minutes. Per Pennsylvania TRM-2016

[281] Table 8. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. For each shower fixture metered, the evaluation team knew the total number of showers taken, duration of time meters remained in each home, and total occupants reported to live in the home. From these values average showers taken per day, per person was calculated. The study compared showers per day, per person by single-family and multifamily populations, finding no statistical difference in the values. For the energy-saving analysis, the study used the combined single-family and multifamily average showers per day, per person of 0.6. Per Pennsylvania TRM-2016

[282] 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

[283] Based on “Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems”, Jim Lutz, Lawrence Berkeley National Laboratory, September 2011.

284 Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

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

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

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*Hours* = *Average number of hours per year spent using shower head*
$= (Time_{Shower} \times \# \text{ people} \times Showers_{Person}) / (ShowerHeads/home \times 60) \times days/year$

Illustrative example – do not use as default assumption
For a 1.5GPM rated showerhead installed through the QHEC program:

*Hours* $= (7.8 \times 2.39 \times 0.6) / (60 \times 1.56) \times 365$
$= 43.6$

*CF* = *Summer Peak Coincidence Factor for measure*
$= 0.00371$[286]

$\Delta kW = 286 / 43.6 * 0.00371$

$= 0.024 \text{ kW}$

**Annual Fossil Fuel Savings Algorithm**

If fossil fuel domestic water heater:

$$\Delta MMBTU = ((GPMbase - GPMlow) \times Time_{shower} \times \# \text{ people} \times Showers_{Person} \times days/year / ShowerHeads/home) \times 8.3 \times 1.0 \times (TEMPsh - TEMPin) / \text{Gas DHW Recovery Efficiency} / 10^6$$

*Where:*

*Gas DHW Recovery Efficiency* = *Recovery efficiency of gas water heater*
$= 0.80$[287]

*All other variables* *As above*

Illustrative example – do not use as default assumption
For a 1.5 GPM rated showerhead installed through the QHEC program:

---

[286] Result of EY3 verification surveys.
0.702 / 180 (minutes in peak period) = 0.00371

[287] 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%.

$\Delta$MMBTU = ((2.5 – 1.5) x 7.8 x 2.39 x 0.6 x 365 / 1.56) x 8.3 x 1.0 x (105 - 60.9) / 0.80 / $10^6$

= 091.2 MMBTU

**Annual Water Savings Algorithm**

Water Savings = ((GPMbase - GPMlow) × $\text{Time}_{\text{shower}}$ × # people × $\textit{Showers}_{\textit{Person}}$ × days/year / ShowerHeads/home) / 748

*Where:*

*748* *= Constant to convert from gallons to CCF*

*All other variables* *As above*

Illustrative example – do not use as default assumption
For a 1.5GPM rated showerhead installed through the QHEC program:

Water Savings = ((2.5 – 1.5) x 7.8 x 2.39 x 0.6 x 365 / 1.56) / 748

= 3.5 CCF

kWh Savings from Water Reduction

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

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

Illustrative example – do not use as default assumption
For a 2.0GPM rated showerhead rebated through the QHEC program:

$\Delta \text{kWh}_{\text{water}}$ = 2.07 * 3.5
= 27.24 kWh

**Measure Life**
The measure life is assumed to be 10 years.[288]

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[288] Consistent with assumptions provided on page C-6 of Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. http://www.energizect.com/sites/default/files/Measure%20Life%20Report%202007.

# Hot Water Tank Wrap

**Unique Measure Code(s): RS_WT_RF_HWWRAP_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

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

### Definition of Baseline Condition

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

### Definition of Efficient Condition

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

### Annual Energy Savings Algorithm

Deemed Energy Savings: 127.33 kWh[289]

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

*Where:*

DkWh = Gross customer annual kWh savings for the measure

$U_{base}$ = Overall heat transfer coefficient prior to adding tank wrap (BTU/Hr-F-$ft^2$)
= See table below. If unknown assume 1/8 [290]

Uinsul = Overall heat transfer coefficient after addition of tank wrap (BTU/Hr-F-ft2)
= See table below. If unknown assume 1/18 [291]

$A_{base}$ = Surface area of storage tank prior to adding tank wrap (square feet)

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[289] Savings are based on previous evaluation research and benchmarking, reported in EY3

[290] Savings are based on previous evaluation research and benchmarking, reported in EY3

[291] Savings are based on previous evaluation research and benchmarking, reported in EY3

= *See table below. If unknown assume 23.18* [292]

$A_{insul}$ = *Surface area of storage tank after addition of tank wrap (square feet)*

= *See table below. If unknown assume 25.31* [293]

$\Delta T$ = *Average temperature difference between tank water and outside air temperature (°F)*

= *60°F* [294]

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

= *8760*

*3412* = *Conversion from BTU to kWh*

$\eta DHW$ = *Recovery efficiency of electric hot water heater*

= *0.98* [295]

The following table has default savings for various tank capacity and pre and post R-VALUES.

| Capacity (gal) | Rbase | Rinsul | Abase (ft2) | ΔkWh | ΔkW |
|---|---|---|---|---|---|
| 30 | 8 | 16 | 19.16 | 171 | 0.019 |
| 30 | 10 | 18 | 19.16 | 118 | 0.014 |
| 30 | 12 | 20 | 19.16 | 86 | 0.010 |
| 30 | 8 | 18 | 19.16 | 194 | 0.022 |
| 30 | 10 | 20 | 19.16 | 137 | 0.016 |
| 30 | 12 | 22 | 19.16 | 101 | 0.012 |
| 40 | 8 | 16 | 23.18 | 207 | 0.024 |
| 40 | 10 | 18 | 23.18 | 143 | 0.016 |
| 40 | 12 | 20 | 23.18 | 105 | 0.012 |
| 40 | 8 | 18 | 23.18 | 234 | 0.027 |
| 40 | 10 | 20 | 23.18 | 165 | 0.019 |
| 40 | 12 | 22 | 23.18 | 123 | 0.014 |
| 50 | 8 | 16 | 24.99 | 225 | 0.026 |
| 50 | 10 | 18 | 24.99 | 157 | 0.018 |
| 50 | 12 | 20 | 24.99 | 115 | 0.013 |
| 50 | 8 | 18 | 24.99 | 255 | 0.029 |
| 50 | 10 | 20 | 24.99 | 180 | 0.021 |

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[292] Savings are based on previous evaluation research and benchmarking, reported in EY3

[293] Savings are based on previous evaluation research and benchmarking, reported in EY3

[294] Savings are based on previous evaluation research and benchmarking, reported in EY3

[295] Savings are based on previous evaluation research and benchmarking, reported in EY3

| | | | | | |
|---|---|---|---|---|---|
| 50 | 12 | 22 | 24.99 | 134 | 0.015 |
| 80 | 8 | 16 | 31.84 | 290 | 0.033 |
| 80 | 10 | 18 | 31.84 | 202 | 0.023 |
| 80 | 12 | 20 | 31.84 | 149 | 0.017 |
| 80 | 8 | 18 | 31.84 | 327 | 0.037 |
| 80 | 10 | 20 | 31.84 | 232 | 0.027 |
| 80 | 12 | 22 | 31.84 | 173 | 0.020 |

If tank specifics are unknown assume 40 gallons as an average tank size[296], and savings from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kWh = ((23.18/8 – 23.18/18) * 60 * 8760) / (3412 * 0.98)$$

$$= 253 \text{ kWh}$$

**Summer Coincident Peak kW Savings Algorithm**

Deemed kW savings: 0.0145 kW[297]

$$\Delta kW \quad = \Delta kWh/8760$$

*Where:*

*ΔkWh = kWh savings from tank wrap installation*

*8760 = Number of hours in a year (since savings are assumed to be constant over year).*

The table above has default savings for various tank capacity and pre and post R-VALUES.

If tank specifics are unknown assume 40 gallons as an average tank size[298], and savings are from adding R-10 to a poorly insulated R-8 tank:

$$\Delta kW \quad = 253 / 8760$$

$$= 0.029 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

n/a

---

[297] Savings are based on previous evaluation research and benchmarking, reported in EY3

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 5 years.[299]

---

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

# High Efficiency Gas Water Heater

**Unique Measure Code: RS_WT_TOS_GASDHW_0415**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

This measure describes the purchase of a high efficiency, residential service, storage or instantaneous (tankless), gas water heater meeting or exceeding ENERGY STAR criteria for the water heater categories provided below, in place of a new unit rated at the minimum Federal Standard. Storage water heaters are between 20 and 100 gallons, having an input rating of ≤75,000 Btu/h. Instantaneous water heaters are rated between 50,000 and 200,000 Btu/h and contain no more than one gallon of water per 4,000 Btu/h of input. The measure could be installed in either an existing or new home. The installation is assumed to occur during a natural time of sale.

### Definition of Baseline Condition

The baseline condition is a new conventional gas storage water heater rated at the federal minimum, effective December 29, 2016[300]. See Efficiency Criteria table below.

### 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[301]:

| **Efficiency Criteria; Consumer Gas Water Heaters** | | | | | |
|---|---|---|---|---|---|
| **Min Uniform Energy Factor (UEF) - based on size and draw pattern** | | | | | |
| **Condition** | **Size (Vs)** | *very small 10GPD* | *low 38GPD* | *medium 55GPD* | *high 84GPD* |
| Base | ≥20 and ≤55 gal | 0.3456 – (0.0020 × Vs) | 0.5982 – (0.0019 × Vs) | 0.6483 – (0.0017 × Vs) | 0.6920 – (0.0013 × Vs) |
| | >55 gal and ≤100 gal | 0.6470 – (0.0006 × Vs) | 0.7689 – (0.0005 × Vs) | 0.7897 – (0.0004 × Vs) | 0.8072 – (0.0003 × Vs) |
| | instantaneous gas <2 gal | 0.80 | 0.81 | 0.81 | 0.81 |
| Efficient | ≤55 gal | NA | NA | 0.64 | 0.68 |
| | >55 gal | NA | NA | 0.78 | 0.80 |
| | instantaneous gas <2 gal | 0.87 | 0.87 | 0.87 | 0.87 |

**UEF calculation example** using a 40 gallon water heater with a medium draw pattern:

---

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

[301] https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria

UEF = 0.6483 – (0.0017 * Vs)
=.643 – (0.0017 * 40)
= .58
Where Vs = 40 gallons

**Determining Draw Pattern**

The relevant hot water draw pattern is specific to usage at the installed location. If actual draw pattern is not known, it can be estimated from the water heater's first hour rating[302] per table below.

If first hour rating is unknown, use medium draw pattern with rated storage capacity ≤50 gallons, and high draw pattern if >50 gallons.[303]

| Draw Pattern based on First Hour Rating | |
|---|---|
| **First Hour Rating** | **Draw Pattern** |
| <18 gallons | Very Small |
| =18 and <51 gallons | Low |
| =51 and <75 gallons | Medium |
| ≥75 gallons | High |

**Annual Energy Savings Algorithm**

n/a

**Summer Coincident Peak kW Savings Algorithm**

n/a

**Annual Fossil Fuel Savings Algorithm**

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

Where:

$UEF_{BASE}$ = *Uniform Energy Factor (efficiency) of standard electric water heater based on minimum federal standards, per efficiency criteria table above.*

$UEF_{EFFICIENT}$ = *Uniform Energy Factor of efficient, installed Heat Pump water heater*

= *Actual. If instantaneous whole-house, multiply rated efficiency by 0.91*[304].

---

[302] CFR part 430 App E 5.4.1

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

[304] The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless/instantaneous units due to significantly higher contributions to overall household hot water usage from

*GPD* = *Gallons Per Day of hot water use per person*
= *45.5 gallons hot water per day per household/2.53people per household*[305]
= *17.6*

*Household* = *Average number of people per household*

= *2.53* [306]

*365.25* = *Days per year, on average*

*γWater = Specific Weight of water*
= *8.33 pounds per gallon*

$T_{out}$ = *Tank temperature*
= *125°F*

$T_{in}$ = *Incoming water temperature from well or municipal system*
= *60.9* [307]

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

Illustrative example – do not use as default assumption
For example, installing a 40 gallon condensing gas storage water heater, with an energy factor of 0.82 in a single family house:

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

**Annual Water Savings Algorithm**
n/a

---

short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. “Field and Laboratory Testing of Tankless Gas Water Heater Performance” Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless/instantaneous category.

[305] US Energy Information Administration, Residential Energy Consumption Survey 2009; http://www.eia.gov/consumption/residential/data/2009/xls/HC9.10%20Household%20Demographics%20in%20South%20Region.xls

[306] Ibid

[307] Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

**Measure Life**
The measure life is assumed to be 13 years[308].

---

[308] 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_0420**
**Effective Date: April 2020**
**End Date: TBD**

## Measure Description

This measure relates to the installation of a Heat Pump domestic water heater with power input rating of <u>≤</u>12kW[309] 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 for a rated storage volume of 55 gallons or less is assumed to be a new electric water heater meeting federal minimum efficiency standards effective December 29, 2016[310]. The baseline condition for a rated storage volume greater than 55 gallons is a weighted average of the federal standard efficiency for alternate equipment reportedly being installed[311]., a UEF of 0.97. This includes commercial-style grid-enabled water heaters (estimated 48%, with UEF of 0.93), multiple smaller water heaters (e.g. two 40-gallon storage hot water heaters installed: 48% with UEF of 0.92) and heat pump water heaters (4% with UEF of 2.06).

## Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified heat pump water heater[312]. A qualifying HPWH's maximum current rating cannot exceed 24 amperes and maximum input voltage cannot exceed 250 Volts. The table below shows the ENERGY STAR qualification criteria. ENERGY STAR maintains a list of qualifying equipment which includes UEF, rather than EF, for 98% of the qualifying models[313].

| | Requirement for EF | Requirement for UEF |
|---|---|---|
| ≤ 55 gallons (Tier 1) | 2.0 | 2.0 |
| > 55 gallons (Tier 2) | 2.2 | 2.2 |
| First Hour Rating | FHR ≥ 50 gallons per hour at 135°F outlet temperature | FHR ≥ 45 gallons per hour at 125°F outlet temperature |

## Annual Energy Savings Algorithm

$\Delta kWh = \Delta kWh\_water + kWh\_cooling - kWh\_heating$

$\Delta kWh\_water = MMBTU/yr * (1/UEF_{BASE} - 1/UEF_{EFFICIENT}) * 293.1$

---

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

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

[311] The federal standard efficiency for electric storage water heaters larger than 55 gallons is approximately 2.0 UEF. The standard indicates baseline equipment is a heat pump water heater. A February 2020 Cadmus study, "EmPOWER Maryland Heat Pump Water Heater Baseline and Market Assessment", determined alternate technology is available and commonly installed in lieu of a heat pump water heater.

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

[313] See https://www.energystar.gov/productfinder/product/certified-water-heaters/results. This page includes a link to an active database of qualified electric water heaters, via link "Access to ENERGY STAR API, Data Set or Excel File".

Where:

ΔkWh_water = Electricity savings directly associated with water heating, does not include interactive effects with home space heating and cooling.

kWh_cooling = Cooling savings from higher efficiency water heating

kWh_heating = Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

MMBTU/yr = annual water heating energy, actual (measured or calculated)

OR, if unknown, by disagregation and accounting for existing water heater efficiency:

= GPD * 365 * γWater * (TOUT – Tin) * 1.0) / 10^6

= 0.195 * GPD

GPD = Gallons Per Day of hot water use per household

= 42.6 gallons per day for hot water heaters with a rated storage volume of 55 gallons or less, and 52.5 gallons per day for hot water heaters with a rated storage volume greater than 55 gallons[314].

365 = Days per year

γWater = Specific weight of water

= 8.33 pounds per gallon

$T_{OUT}$ = Tank temperature

= 125°F

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

= 60.9 [315]

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

10^6 = Conversion from BTU to MMBtu

$UEF_{BASE}$ = See “Consumer Electric Storage Water Heater Baseline Efficiency Criteria” table in the “Reference Tables” section below.

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[314] EmPOWER heat pump water heater program participation in 2018-2019 and participant survey data.

[315] Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs.” April 4, 2014, Appendix E, page 66.

$UEF_{EFFICIENT}$ = Uniform Energy Factor of efficient, installed Heat Pump water heater

= Actual

293.1 = Conversion from MMBTU to kWh

Annual Cooling % = estimated portion of days of the year with air conditioning use

= 35%[316]

$LF_C$ = Location Factor, cooling

= 1.0 for HPWH installation in a conditioned space

= 0.65 for HPWH installation in an unknown location[317]

= 0.0 for installation in an unconditioned space

$WMF_C$ = Water Main Factor, cooling

= 0.82[318]

$COP_{COOL}$ = COP of central air conditioning

= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

Annual Heating % = estimated portion of days of the year with heating use

= 47%[319]

$LF_H$ = Location Factor, heating

= 1.0 for HPWH installation in a heated space

= 0.8 for HPWH installation in an unknown location[320]

= 0.0 for installation in an unconditioned space

$WMF_H$ = Water Main Factor, heating

---

[316] Cadmus, “EmPOWER Maryland Heat Pump Water Heater Baseline and Market Analysis”, February 2020.

[317] Ibid.

[318] From March 2020 Guidehouse analysis, “Monthly Hot Water Use_GHv2.xlsx”. Water heating energy per gallon delivered is reduced in the cooling season months due to warmer well or municipal systems temperatures.

[319] Cadmus, “EmPOWER Maryland Heat Pump Water Heater Baseline and Market Analysis”, February 2020

[320] Ibid.

= *1.14*[321]

$COP_{HEAT}$ = *COP of electric heating system*

= *actual. If not available, use*[322]*:*

| System Type | $COP_{HEAT}$ |
|---|---|
| Natural Gas or other Fossil Fuel | 0 |
| Heat Pump | 2.04 |
| GSHP | 3.1 |
| Resistance | 1.00 |
| Unknown | 1.95 |

### Summer Coincident Peak kW Savings Algorithm

For water heaters with a rated storage volume of 55 gallons or less:

$$\Delta kW = 0.09 * UEF_{EFFICIENT} / 3.41$$ [323]

For water heaters with a rated storage volume greater than 55 gallons:

$$\Delta kW = 0.11 * UEF_{EFFICIENT} / 3.34$$ [324]

### Annual Fossil Fuel Savings Algorithm

For natural gas home heating systems:

$$\Delta MMBTU = - \Delta kWh\_water * Annual\ Heating\% * LF_H / \eta Heat$$

*Where:*

$\eta Heat$ = *Efficiency of natural gas heating system*

---

[321] From March 2020 Guidehouse analysis, “Monthly Hot Water Use_GHv2.xlsx”. Water heating energy per gallon delivered is increased in the heating season months due to colder well or municipal systems temperatures.

322 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.

[323] Analysis of special study. Cadmus, “EmPOWER Maryland Heat Pump Water Heater Baseline and Market Analysis”, February 2020. The study leveraged HPWH load shapes from “Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters” (https://www.energy.gov/sites/prod/files/2014/01/f7/heat_pump_water_heater_testing.pdf).

[324] Ibid

*= Actual.*[325] *If not available, use 84%.*[326]

For unknown, electric resistance, heat pump or GSHP home heating systems:

ΔMMBTU = 0.

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 13 years.[327]

**Reference Tables**

**Consumer Electric Storage Water Heater Baseline Efficiency Criteria**

| | | **Uniform Energy Factor (UEF) - based on draw pattern** | | | |
|---|---|---|---|---|---|
| **Condition** | **Rated Storage Volume (Vs)** | *very small 10GPD* | *low 38GPD* | *medium 55GPD* | *high 84GPD* |
| Baseline | ≥20 and ≤55 gal | 0.8808 – (0.0008 × Vs) | 0.9254 – (0.0003 × Vs) | 0.9307 – (0.0002 × Vs) | 0.9349 – (0.0001 × Vs) |
| | >55 gal and ≤120 gal* | 1.9236 – (0.0011 × Vs) | 2.0440 – (0.0011 × Vs) | 2.1171 – (0.0011 × Vs) | 2.2418 – (0.0011 × Vs) |

*UEF values represent efficiency standards for residential electric storage water heaters. An average baseline efficiency based on electric water heaters being installed is UEF of 0.97. See "Definition of Baseline Condition" for this measure.

---

[325] 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.

[326] This has been estimated assuming typical efficiencies of existing heating systems weighted by percentage of homes with non-electric heating (based on Energy Information Administration, 2009 Residential Energy Consumption Survey: http://www.eia.gov/consumption/residential/data/2009/xls/HC6.9%20Space%20Heating%20in%20Midwest%20Region.xls).

[327] DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Page 8-52 http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf

**Determining Draw Pattern**

The relevant hot water draw pattern is specific to usage at the installed location. If actual draw pattern is not known, it can be estimated from the water heater's first hour rating[328] per table below.

If first hour rating is unknown, use medium draw pattern with rated storage capacity ≤50 gallons, and high draw pattern if >50 gallons.[329]

| Draw Pattern based on First Hour Rating | |
|---|---|
| **First Hour Rating** | **Draw Pattern** |
| <18 gallons | Very Small |
| =18 and <51 gallons | Low |
| =51 and <75 gallons | Medium |
| ≥75 gallons | High |

---

[328] CFR part 430 App E 5.4.1

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

# Thermostatic Restrictor Shower Valve

**Unique Measure Code: RS_HV_RF_GSHPS_0415, RS_HV_NC_GSHPS_0415**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

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

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

### Definition of Baseline Condition

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

### Definition of Efficient Condition

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

### Annual Energy Savings Algorithm

ΔkWh = %ElectricDHW * ((GPM_base_S * L_showerdevice) * Household * SPCD * 365 / SPH) * EPG_electric

*Where:*

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

| *DHW fuel* | *%ElectricDHW* |
|---|---|
| *Electric* | *100%* |
| *Natural Gas* | *0%* |
| *Unknown* | *24%*[330] |

*GPM_base_S = Flow rate of the basecase showerhead, or actual if available*

| *Program* | *GPM* |
|---|---|
| *Direct-install, device only* | *2.5* [331] |

---

[330] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Atlantic Region. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

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

| | |
|---|---|
| *New Construction or direct install of device and low flow showerhead* | *Rated or actual flow of program-installed showerhead* |

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

*= 0.89 minutes*[332]

*Household* *= Average number of people per household*

= 2.39[333].

*SPCD* *= Showers Per Capita Per Day*

*= 0.6*[334]

*365* *= Days per year, on average.*

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

*= 1.56 for QHEC and 2.46 for HPwES. This is the result of EY3 verification surveys.*

*= 1.6 for all other channels* [335]

*EPG_electric* *= Energy per gallon of hot water supplied by electric*

*= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)*

*= (8.33 * 1.0 * (105 – 60.9)) / (0.98 * 3412)*

---

[332] Average of the following sources: ShowerStart LLC survey; “Identifying, Quantifying and Reducing Behavioral Waste in the Shower: Exploring the Savings Potential of ShowerStart”, City of San Diego Water Department survey; “Water Conservation Program: ShowerStart Pilot Project White Paper”, and PG&E Work Paper PGECODHW113.

[333] This is the average from three separate sources: the Mid-Atlantic TRM V7, Pennsylvania TRM, and Wisconsin Focus on Energy TRM.

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

[335] 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

*= 0.11 kWh/gal*

*8.33 = Specific weight of water (lbs/gallon)*

*1.0 = Specific heat capacity of water (BTU/lb-°F)*

*ShowerTemp = Assumed temperature of water*

*= 105* [336]

*SupplyTemp = Assumed temperature of water entering house*

*= 60.9* [337]

*RE_electric = Recovery efficiency of electric water heater*

*= 98%* [338]

*3412 = Constant to convert BTU to kWh*

Illustrative Example - do not use as default assumption

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

ΔkWh = 1.0 * (2.5 * 0.89 * 2.39 * 0.6 * 365.25 / 1.6) * 0.11

= 80.1 kWh

**Summer Coincident Peak kW Savings Algorithm**

ΔkW = ΔkWh/Hours * CF

*Where:*

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

*= ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH ) * 0.746*[339] */ GPH*

*GPH = Gallons per hour recovery of electric water heater calculated for 59.1 temp rise (120-60.9), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.*

---

[336] Based on "Water and Energy Wasted During Residential Shower Events: Findings from a Pilot Field Study of Hot Water Distribution Systems", Jim Lutz, Lawrence Berkeley National Laboratory, September 2011.

337 Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Residential Retrofit Programs." April 4, 2014, Appendix E, page 66.

[338] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

[339] 74.6% is the proportion of hot 120F water mixed with 60.1F supply water to give 105F shower water.

*= 30.0*

*Hours* *= ((2.5 * 0.89) * 2.39 * 0.6 * 365.25 / 1.6) * 0.746 / 30*

*= 18.1 hours*

*CF* *= Coincidence Factor for electric load reduction*

*= 0.00371*[340]

Illustrative example – do not use as default assumption

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

ΔkW = 80.1 / 18.1 * 0.0015

= 0.007 kW

**Annual Fossil Fuel Savings Algorithm**

ΔMMBTU = %FossilDHW * ((GPM_base_S * L_showerdevice)* Household * SPCD * 365.25 / SPH) * EPG_gas

*Where:*

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

| *DHW fuel* | *%Fossil_DHW* |
|---|---|
| *Electric* | *0%* |
| *Natural Gas* | *100%* |
| *Unknown* | *76%*[341] |

*EPG_gas* *= Energy per gallon of Hot water supplied by gas*

*= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_gas * 1,000,000)*

*= 0.00065 MMBTU/gal*

*RE_gas = Recovery efficiency of gas water heater*

---

[340] See Low-Flow Showerhead measure

[341] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Mid Attlantic Region. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

*= 75% For SF homes*[342]

*1,000,000* *= Converts BTUs to MMBTU*

*Other variables as defined above.*

Illustrative example – do not use as default assumption

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

ΔMMBTU = 1.0 * ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) * 0.00065
= 0.51 MMBTU

**Water impact Descriptions and calculations**

ΔCCF = ((GPM_base_S * L_showerdevice) * Household * SPCD * 365.25 / SPH) / 748

*Where:*

*748* *= Constant to convert from gallons to CCF*

*Other variables as defined above*

Illustrative example – do not use as default assumption

For example, a direct installed valve:

ΔCCF = ((2.5 * 0.89) * 2.56 * 0.6 * 365.25 / 1.6) / 748
= 1.0 CCF

**Measure Life**

The expected measure life is assumed to be 10 years. [343]

---

[342] DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 75%.

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

# Water Heater Temperature Setback

**Unique Measure Code: RS_WT_RF_WHTSB_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to turning down an existing hot water tank thermostat setting that is at 130 degrees or higher. Savings are provided to account for the resulting reduction in standby losses. This is a retrofit measure.

### Definition of Baseline Equipment

The baseline condition is a hot water tank with a thermostat setting that is 130 degrees or higher. Note if there are more than one DHW tanks in the home at or higher than 130 degrees and they are all turned down, then the savings per tank can be multiplied by the number of tanks.

### Definition of Efficient Equipment

The efficient condition is a hot water tank with the thermostat reduced to no lower than 120 degrees.

### Annual Energy Savings Algorithm

For homes with electric DHW tanks:

Deemed Energy Savings: 185.46 kWh[344]

ΔkWh[345] = (UA * (Tpre – Tpost) * Hours) / (3412 * RE_electric)

*Where:*

*U* = *Overall heat transfer coefficient of tank (BTU/Hr-°F-$ft^2$).*

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

*A* = *Surface area of storage tank (square feet)*

---

[344] Savings are based on previous evaluation research and benchmarking, reported in EY3

[345] Note this algorithm provides savings only from reduction in standby losses. VEIC considered avoided energy from not heating the water to the higher temperature but determined that the potential impact for the three major hot water uses was too small to be characterized; Dishwashers are likely to boost the temperature within the unit (roughly canceling out any savings), faucet and shower use is likely to be at the same temperature so there would need to be more lower temperature hot water being used (cancelling any savings) and clothes washers will only see savings if the water from the tank is taken without any temperature control.

*= Actual if known. If unknown use table below based on capacity of tank. If capacity unknown assume 50 gal tank; A = 24.99* $ft^2$

| *Capacity (gal)* | *A* ($ft^2$)[346] |
|---|---|
| *30* | *19.16* |
| *40* | *23.18* |
| *50* | *24.99* |
| *80* | *31.84* |

*Tpre* *= Actual hot water setpoint prior to adjustment.*

*= 135 degrees default*

*Tpost* *= Actual new hot water setpoint, which may not be lower than 120 degrees*

*= 120 degrees default*

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

*= 8760*

*3412* *= Conversion from BTU to kWh*

*RE_electric* *= Recovery efficiency of electric hot water heater*

*= 0.98* [347]

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

ΔkWh = (UA * (Tpre – Tpost) * Hours) / (3412 * RE_electric)

= (((0.083 * 24.99) * (135 – 120) * 8760) / (3412 * 0.98)

= 81.5 kWh

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[346] Assumptions from Pennsylvania TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

[347] Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx

**Summer Coincident Peak kW Savings Algorithm**

Deemed Demand Savings: 0.0212 kW[348]

ΔkW = ΔkWh / Hours

*Where:*

*Hours = 8760*

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

ΔkW = (81.5/ 8760)

= 0.0093 kW

**Annual Fossil Fuel Savings Algorithm**

For homes with gas water heaters:

ΔMMBTU = (U * A * (Tpre – Tpost) * Hours) / (1,000,000 * RE_gas)

*Where*

*1,000,000 = Converts BTUs to MMBTU (BTU/MMBTU)*

*RE_gas = Recovery efficiency of gas water heater*

*= 0.75* [349]

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

ΔMMBTU = (U * A * (Tpre – Tpost) * Hours) / (1,000,000 * RE_gas)

= (0.083 * 24.99 * (135 – 120) * 8760) / (1,000,000 * 0.75)

= 0.36 MMBTU

**Annual Water Savings Algorithm**

N/A

**Deemed Lifetime of Efficient Equipment**

The assumed lifetime of the measure is 2 years.

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[348] Savings are based on previous evaluation research and benchmarking, reported in EY3

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

*Appliance End Use*

# Clothes Washer

**Unique Measure Code(s): RS_LA_TOS_CWASHES_0420, RS_LA_TOS_CWASHT2_0420, RS_LA_TOS_CWASHT3_0420, RS_LA_TOS_CWASHME_0420**

**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the purchase (time of sale) and installation of a clothes washer exceeding either the ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE Tier 3 minimum qualifying efficiency standards presented below. [350,351]

| Efficiency Level | Integrated Modified Energy Factor (IMEF) | | Integrated Water Factor (IWF) | |
|---|---|---|---|---|
| | Front Loading | Top Loading | Front Loading | Top Loading |
| **Clothes washers >2.5 cu. Ft.** | | | | |
| ENERGY STAR | ≥ 2.76 | ≥ 2.06 | ≤3.2 | ≤4.3 |
| CEE TIER 1 | ≥ 2.76 | ≥ 2.76 | ≤3.2 | ≤3.2 |
| CEE TIER 2 | ≥ 2.92 | ≥ 2.92 | ≤3.2 | ≤3.2 |
| CEE TIER 3 | ≥ 3.10 | ≥ 3.10 | ≤3.0 | ≤3.0 |
| **Clothes washers ≤2.5 cu. Ft.** | | | | |
| ENERGY STAR | ≥ 2.07 | | ≤4.2 | |
| CEE TIER 1 | ≥ 2.07 | | ≤4.2 | |
| CEE TIER 2 | ≥ 2.20 | | ≤3.7 | |

The Integrated Modified Energy Factor (IMEF) measures energy consumption of the total laundry cycle (washing and drying). It indicates how many cubic feet of laundry can be washed and dried with one kWh of electricity and the per-cycle standby and off mode energy consumption; the higher the number, the greater the efficiency.

The Integrated Water Factor (IWF) is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

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[350] https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria

[351] https://library.cee1.org/system/files/library/13445/CEE_ResidentialClothesWasherSpecification_05Feb2018.pdf

Only front and top-loading clothes washers with capacities greater than 1.6 ft3 and less than 8.0 ft3; and that are not defined as Combination All-In One Washer-Dryers, Residential Clothes Washers with Heated Drying Functionality, or top-loading commercial clothes washers are eligible for ENERGY STAR Certification.

### Definition of Baseline Condition

The baseline efficiency is determined according to the Integrated Modified Energy Factor (IMEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle and standby/off mode consumption. The federal baseline changed as of January 1, 2018.[352] Note that the criteria below are for standard units of 1.6 cubic feet or greater. Separate criteria are provided for compact clothes washers (<1.6 cubic feet), but they are not included here as they are not eligible for ENERGY STAR qualification.

| Efficiency Level | Integrated Modified Energy Factor (IMEF) | | Integrated Water Factor (IWF) | |
|---|---|---|---|---|
| | Front Loading | Top Loading | Front Loading | Top Loading |
| After Jan 1, 2018 | 1.84 | 1.57 | 4.7 | 6.5 |

### Definition of Efficient Condition

The efficient condition is a clothes washer meeting either the ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE TIER 3 efficiency criteria presented above.

### Annual Energy Savings Algorithm

$$\Delta kWh = [(Capacity * 1/IMEFbase * Ncycles) * (\%CWbase + (\%DHWbase * \%Electric\_DHW) + (\%Dryerbase * \%Electric\_Dryer)] - [(Capacity * 1/IMEFeff * Ncycles) * (\%CWeff + (\%DHWeff * \%Electric\_DHW) + (\%Dryereff * \%Electric\_Dryer)]$$

*Where*

*Capacity* = *Clothes Washer capacity (cubic feet)*
= *Actual. If capacity is unknown assume average 3.39 cubic feet*[353]
*IMEFbase* = *Integrated Modified Energy Factor of baseline unit*
= *Values provided in table below*
*IMEFeff* = *Integrated Modified Energy Factor of efficient unit*
= *Actual. If unknown assume average values provided below.*

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[352] https://www.ecfr.gov/cgi-bin/text-idx?SID=86e70cbc87e5af18caca2e5c205bd107&mc=true&node=se10.3.430_132&rgn=div8

353 Based on the average clothes washer volume of all units that are ENERGY STAR qualified as of 3/17/2020.

| Efficiency Level | Integrated Modified Energy Factor (IMEF) | | | Weighting Percentage[354] | |
|---|---|---|---|---|---|
| | Front Loading | Top Loading | Weighted Average | Front Loading | Top Loading |
| **Clothes washers >2.5 cu. Ft.** | | | | | |
| Federal Standard | ≥1.84 | ≥1.57 | ≥1.72 | 54% | 46% |
| ENERGY STAR | ≥2.76 | ≥ 2.06 | ≥2.22 | 23% | 77% |
| CEE TIER 1 | ≥2.76 | ≥ 2.06 | ≥2.22 | 23% | 77% |
| CEE TIER 2 | ≥ 2.92 | | ≥2.92 | 100% | 0% |
| CEE TIER 3 | ≥ 3.10 | | ≥3.10 | 100% | 0% |
| **Clothes washers ≤2.5 cu. Ft.** | | | | | |
| Federal Standard | ≥1.84 | ≥1.57 | ≥1.84 | 100% | 0% |
| ENERGY STAR | ≥2.07 | | ≥2.07 | 100% | 0% |
| CEE TIER 1 | ≥2.07 | | ≥2.07 | 100% | 0% |
| CEE TIER 2 | ≥2.20 | | ≥2.20 | 100% | 0% |

*Ncycles = Number of Cycles per year*
*= 254*[355]
*%CW = Percentage of total energy consumption for Clothes Washer operation*
*%DHW = Percentage of total energy consumption used for water heating*
*%Dryer = Percentage of total energy consumption for dryer operation (dependent on efficiency level – see table below)*

| Efficiency Level | Percentage of Total Energy Consumption[356] | | |
|---|---|---|---|
| | %CW | %Dryer | %DHW |
| Federal Standard | 7% | 65% | 28% |
| **Clothes washers (>2.5 cu. Ft.)** | | | |
| ENERGY STAR | 5% | 63% | 32% |
| CEE TIER 1 | 5% | 63% | 32% |
| CEE TIER 2 | 10% | 87% | 3% |

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[354] Weightings based on ENERGY STAR qualified product list accessed on 3/17/2020.

[355] Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

[356] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units (based on available product from the ENERGY STAR qualified product list accessed on 3/17/2020) and consumption data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: https://www.regulations.gov/docketBrowser?rpp=25&so=DESC&sb=commentDueDate&po=0&dct=SR&D=EERE-2008-BT-STD-0019 .

| | | | |
|---|---|---|---|
| CEE TIER 3 | 10% | 87% | 3% |
| **Clothes washers ≤2.5 cu. Ft.** | | | |
| CEE TIER 1 | 8% | 72% | 20% |
| CEE TIER 2 | 8% | 72% | 20% |

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

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |
| Unknown | 31%[357] |

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

| Dryer fuel | %Electric_Dryer |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |
| Unknown | 68%[358] |

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

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*Hours* = *Assumed Run hours of Clothes Washer*
= *265* [359]

*CF* = *Summer Peak Coincidence Factor for measure*
= *0.029* [360]

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[357] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2015 for Mid Atlantic States.

[358] Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Mid Atlantic States.

[359] Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

[360] Ibid.

### Annual Fossil Fuel Savings Algorithm

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

*Where:*

*R_eff = Recovery efficiency factor*
*= 1.26*[361]
*MMBtu _convert = Conversion factor from kWh to MMBtu*
*= 0.003413*

*%Fossil Fuel DHW = Percentage of DHW savings assumed to be Fossil fuel*

| DHW fuel | %Natural Gas_DHW |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |
| Unknown | 69%[362] |

*%Gas Dryer = Percentage of dryer savings assumed to be Natural Gas*

| Dryer fuel | %Gas_Dryer |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 32%[363] |

*Other factors as defined above*

### Annual Water Savings Algorithm

ΔWater (CCF) = (Capacity * (IWFbase - IWFeff)) * Ncycles / 748 gallons/CCF

*Where*

*IWFbase = Integrated Water Factor of baseline clothes washer*
*= Values provided below (gallons/CF of washer capacity)*

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[361] To account for the different efficiency of electric and Fossil fuel water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf ). Therefore, a factor of 0.98/0.78 (1.26) is applied.

[362] Default assumption for unknown fuel is based on percentage of homes with gas DHW from EIA Residential Energy Consumption Survey (RECS) 2015 for Mid Atlantic States.

[363] Default assumption for unknown is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2015 for Mid Atlantic States.

*IWFeff* *= Integrated Water Factor of efficient clothes washer (gallons/CF of washer capacity)*
*= Actual. If unknown assume average values provided below.*

| Efficiency Level | Integrated Water Factor (IWF) | | |
|---|---|---|---|
| | Front Loading | Top Loading | Weighted Average |
| **Standard sized clothes washers (>2.5 cu. Ft.)** | | | |
| Federal Standard | 4.7 | 6.5 | 5.5 |
| ENERGY STAR | 3.2 | 4.3 | 4.0 |
| CEE Tier 1 | 3.2 | 4.3 | 4.0 |
| CEE TIER 2 | 3.2 | 3.2 | 3.2 |
| CEE TIER 3 | 3.0 | 3.0 | 3.0 |
| **Standard sized clothes washers (>2.5 cu. Ft.)** | | | |
| Federal Standard | 4.7 | | 4.7 |
| ENERGY STAR | 4.2 | | 4.2 |
| CEE Tier 1 | 4.2 | | 4.2 |
| CEE TIER 2 | 3.7 | | 3.7 |

The prescriptive water savings for each efficiency level are presented below:

| Efficiency Level | Δ Water (ccf per year) | | |
|---|---|---|---|
| | Front Loading | Top Loading | Weighted Average |
| **Standard sized clothes washers (>2.5 cu. Ft.)** | | | |
| ENERGY STAR | 2.4 | 3.5 | 2.4 |
| CEE Tier 1 | 2.4 | 3.5 | 2.4 |
| CEE TIER 2 | 2.4 | 5.3 | 3.7 |
| CEE TIER 3 | 2.7 | 5.6 | 4.0 |
| **Standard sized clothes washers (>2.5 cu. Ft.)** | | | |
| ENERGY STAR | 0.4 | | 0.4 |
| CEE Tier 1 | 0.4 | | 0.4 |
| CEE TIER 2 | 0.8 | | 0.8 |

**kWh Savings from Water Reduction**

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

$$\Delta kWh_{water}{}^{364} = 2.07\ kWh * \Delta Water\ (CCF)$$

**Measure Life**

The measure life is assumed to be 14 years [365].

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[364] This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

[365] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: https://www.regulations.gov/docketBrowser?rpp=25&so=DESC&sb=commentDueDate&po=0&dct=SR&D=EERE-2008-BT-STD-0019

# Clothes Washer Early Replacement

**Unique Measure Code(s): RS_LA_RTR_CWASHES_0420, RS_LA_ RTR_CWASHT2_0420, RS_LA_ RTR_CWASHT3_0420, RS_LA_ RTR_CWASHME_0420**

**Effective Date: April 2020**
**End Date: TBD**

**Measure Description**
This measure relates to the early removal of an existing inefficient clothes washer from service, prior to its natural end of life, and replacement with a new unit exceeding either the ENERGY STAR, CEE Tier 1, CEE Tier 2 or CEE Tier 3 minimum qualifying efficiency standards presented below.[366,367]

| Efficiency Level | Integrated Modified Energy Factor (IMEF) | | Integrated Water Factor (IWF) | |
|---|---|---|---|---|
| | Front Loading | Top Loading | Front Loading | Top Loading |
| **Clothes washers >2.5 cu. Ft.** | | | | |
| ENERGY STAR | ≥ 2.76 | ≥ 2.06 | ≤3.2 | ≤4.3 |
| CEE TIER 1 | ≥ 2.76 | ≥ 2.76 | ≤3.2 | ≤3.2 |
| CEE TIER 2 | ≥ 2.92 | ≥ 2.92 | ≤3.2 | ≤3.2 |
| CEE TIER 3 | ≥ 3.10 | ≥ 3.10 | ≤3.0 | ≤3.0 |
| **Clothes washers ≤2.5 cu. Ft.** | | | | |
| ENERGY STAR | ≥ 2.07 | | ≤4.2 | |
| CEE TIER 1 | ≥ 2.07 | | ≤4.2 | |
| CEE TIER 2 | ≥ 2.20 | | ≤3.7 | |

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

The Integrated Water Factor (IWF) is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

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[366] https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria
[367] https://library.cee1.org/system/files/library/13445/CEE_ResidentialClothesWasherSpecification_05Feb2018.pdf

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.

Only front and top-loading clothes washers with capacities greater than 1.6 $ft^3$ and less than 8.0 $ft^3$; and that are not defined as Combination All-In One Washer-Dryers, Residential Clothes Washers with Heated Drying Functionality, or top-loading commercial clothes washers are eligible for ENERGY STAR Certification.

**Definition of Baseline Condition**
The baseline condition is the existing inefficient clothes washer for the remaining assumed useful life of the unit, assumed to be 5 years[368], and then for the remainder of the measure life (next 9 years) the baseline becomes a new replacement unit meeting the minimum federal efficiency standard presented above.

The existing unit efficiency is assumed to be 1.0 IMEF for front loaders and 0.84 IMEF for top loaders. This is based on the Federal Standard for clothes washers from 2007 - 2015; 1.26 MEF converted to IMEF using an ENERGY STAR conversion tool copied into the reference calculation spreadsheet “2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls”. The Integrated Water Factor is assumed to be 8.2 IWF for front loaders and 8.4 for top loaders, based on a similar conversion of the 2004 Federal Standard 7.93 WF.

The new baseline unit is consistent with the Time of Sale measure.

The baseline assumptions are provided below:

| Efficiency Level | Integrated Modified Energy Factor (IMEF) | | Integrated Water Factor (IWF) | |
|---|---|---|---|---|
| | Front Loading | Top Loading | Front Loading | Top Loading |
| Existing unit | 1.0 | 0.84 | 8.2 | 8.4 |
| Federal Standard after Jan 1, 2018 | 1.84 | 1.57 | 4.7 | 6.5 |

**Definition of Efficient Condition**
The efficient condition is a clothes washer meeting either the exceeding ENERGY STAR, CEE Tier 1, CEE Tier 2 or CEE Tier 3 standards as of 1/1/2015 as presented in the measure description.

**Annual Energy Savings Algorithm**
(see ‘2015 Mid Atlantic Early Replacement Clothes Washer Analysis.xls’ for detailed calculation)

ΔkWh = [(Capacity * 1/IMEFbase * Ncycles) * (%CWbase + (%DHWbase * %Electric_DHW) + (%Dryerbase * %Electric_Dryer)] - [(Capacity * 1/IMEFeff *

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

Ncycles) * (%CWeff + (%DHWeff * %Electric_DHW) + (%Dryereff * %Electric_Dryer)]

*Where*

*Capacity = Clothes Washer capacity (cubic feet)*
*= Actual. If capacity is unknown assume average 3.39 cubic feet*[369]
*IMEFbase = Integrated Modified Energy Factor of baseline unit*
*= Values provided in table below*
*IMEFeff = Integrated Modified Energy Factor of efficient unit*
*= Actual. If unknown assume average values provided below.*

| Efficiency Level | Integrated Modified Energy Factor (IMEF) | | | Weighting Percentage[370] | |
|---|---|---|---|---|---|
| | Front Loading | Top Loading | Weighted Average | Front Loading | Top Loading |
| Existing Unit[371] | 1.0 | 0.84 | n/a[372] | n/a | n/a |
| **Clothes washers >2.5 cu. Ft.** | | | | | |
| Federal Standard | ≥1.84 | ≥1.57 | ≥1.72 | 54% | 46% |
| ENERGY STAR | ≥2.76 | ≥ 2.06 | ≥2.22 | 23% | 77% |
| CEE TIER 1 | ≥2.76 | ≥ 2.06 | ≥2.22 | 23% | 77% |
| CEE TIER 2 | ≥ 2.92 | | ≥2.92 | 100% | 0% |
| CEE TIER 3 | ≥ 3.10 | | ≥3.10 | 100% | 0% |
| **Clothes washers ≤2.5 cu. Ft.** | | | | | |
| Federal Standard | ≥1.84 | ≥1.57 | ≥1.84 | 100% | 0% |
| ENERGY STAR | ≥2.07 | | ≥2.07 | 100% | 0% |
| CEE TIER 1 | ≥2.07 | | ≥2.07 | 100% | 0% |
| CEE TIER 2 | ≥2.20 | | ≥2.20 | 100% | 0% |

*Ncycles = Number of Cycles per year*
*= 254*[373]
*%CW = Percentage of total energy consumption for Clothes Washer operation*
*%DHW = Percentage of total energy consumption used for water heating*

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[369] Based on the average clothes washer volume of all units that are ENERGY STAR qualified as of 3/17/2020.

[370] Weightings based on ENERGY STAR qualified product list accessed on 3/17/2020.

[371] Existing units efficiencies are based upon an MEF of 1.26 , the 2004 Federal Standard, converted to IMEF using an ENERGY STAR conversion tool.

[372] For early replacement measures we will always know the configuration of the replaced machine.

[373] Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

*%Dryer* = *Percentage of total energy consumption for dryer operation (dependent on efficiency level – see table below)*

| Efficiency Level | Percentage of Total Energy Consumption[374] | | |
|---|---|---|---|
| | %CW | %Dryer | %DHW |
| Federal Standard | 7% | 65% | 28% |
| **Clothes washers (>2.5 cu. Ft.)** | | | |
| ENERGY STAR | 5% | 63% | 32% |
| CEE TIER 1 | 5% | 63% | 32% |
| CEE TIER 2 | 10% | 87% | 3% |
| CEE TIER 3 | 10% | 87% | 3% |
| **Clothes washers ≤2.5 cu. Ft.** | | | |
| CEE TIER 1 | 8% | 72% | 20% |
| CEE TIER 2 | 8% | 72% | 20% |

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

| DHW fuel | %Electric_DHW |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |

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

| Dryer fuel | %Electric_Dryer |
|---|---|
| Electric | 100% |
| Fossil Fuel | 0% |

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

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*Hours* = *Assumed Run hours of Clothes Washer*

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[374] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units (based on available product from the ENERGY STAR qualified product list accessed on 3/17/2020) and consumption data from Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: https://www.regulations.gov/docketBrowser?rpp=25&so=DESC&sb=commentDueDate&po=0&dct=SR&D=EERE-2008-BT-STD-0019 .

= 265 [375]

CF = Summer Peak Coincidence Factor for measure

= 0.029 [376]

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

### Annual Fossil Fuel Savings Algorithm

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas DHW and Natural Gas dryer savings from total savings:

ΔMMBtu = [(Capacity * 1/IMEFbase * Ncycles) * ((%DHWbase * %Fossil fuel_DHW * R_eff) + (%Dryerbase * %Gas _Dryer)] - [(Capacity * 1/IMEFeff * Ncycles) * ((%DHWeff * %Fossil Fuel_DHW * R_eff) + (%Dryereff * %Gas_Dryer)] * MMBtu_convert

*Where:*

*R_eff* = *Recovery efficiency factor*

= *1.26*[377]

*MMBtu _convert* = *Convertion factor from kWh to MMBtu*

= *0.003413*

*%Natural Gas_DHW* = *Percentage of DHW savings assumed to be Natural Gas*

| DHW fuel | %Natural Gas_DHW |
|---|---|
| Electric | 0% |
| Fossil Fuel | 100% |

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

| Dryer fuel | %Gas_Dryer |
|---|---|
| Electric | 0% |
| Natural Gas | 100% |

*Other factors as defined above*

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[375] Metered data from Navigant Consulting “EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program.” March 21, 2014, page 36.

[376] Ibid.

[377] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf ). Therefore a factor of 0.98/0.78 (1.26) is applied.

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

**Annual Water Savings Algorithm**

ΔWater (CCF) = (Capacity * (IWFbase - IWFeff)) * Ncycles / 748 gallons / CCF

*Where*

*WFbase* = *Integrated Water Factor of baseline clothes washer*
= *Values provided below*

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

| Efficiency Level | Integrated Water Factor (IWF) | | |
|---|---|---|---|
| | Front Loading | Top Loading | Weighted Average[378] |
| Existing Unit | 8.2 | 8.4 | n/a[379] |
| **Standard sized clothes washers (>2.5 cu. Ft.)** | | | |
| Federal Standard | 4.7 | 6.5 | 5.5 |
| ENERGY STAR | 3.2 | 4.3 | 4.0 |
| CEE Tier 1 | 3.2 | 4.3 | 4.0 |
| CEE TIER 2 | 3.2 | 3.2 | 3.2 |
| CEE TIER 3 | 3.0 | 3.0 | 3.0 |
| **Standard sized clothes washers ≤2.5 cu. Ft.)** | | | |
| Federal Standard | 4.7 | | 4.7 |
| ENERGY STAR | 4.2 | | 4.2 |
| CEE Tier 1 | 4.2 | | 4.2 |
| CEE TIER 2 | 3.7 | | 3.7 |

**kWh Savings from Water Reduction**

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

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[378] Weighting based on model availability on the ENERGY STAR qualified product list accessed on 3/17/2020.

[379] For early replacement we will always know the unit configuration of the replaced unit.

$\Delta kWh_{water}$[380] $= 2.07\ kWh * \Delta Water\ (CCF)$

**Measure Life**

The measure life is assumed to be 14 years [381] and the existing unit is assumed to have a remaining life of 5 years[382].

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[380] This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

[381] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm

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

# Clothes Dryer

**Unique Measure Code(s): RS_AP_TOS_CLTDRY_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a residential clothes dryer meeting the ENERGY STAR criteria. ENERGY STAR qualified clothes dryers save energy through a combination of more efficient drying and reduced runtime of the drying cycle. More efficient drying is achieved through increased insulation, modifying operating conditions such as air flow and/or heat input rate, improving air circulation through better drum design or booster fans, and improving efficiency of motors. Reducing the runtime of dryers through automatic termination by temperature and moisture sensors is believed to have the greatest potential for reducing energy use in clothes dryers[383]. ENERGY STAR provides criteria for both gas and electric clothes dryers.

### Definition of Baseline Condition

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

### Definition of Efficient Condition

Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

### Annual Energy Savings Algorithm

$$\Delta kWh = (Load/CEFbase - Load/CEFeff) * Ncycles * \%Electric$$

*Where:*

*Load* = *The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.*

| *Dryer Size* | *Load (lbs.)[384]* |
|---|---|
| *Standard* | *8.45* |
| *Compact* | *3* |

*CEFbase* = *Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis[385]. If*

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[383] ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. Table 8. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

[384] Based on ENERGY STAR test procedures. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[385] ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

*product class unknown, assume electric, standard.*

| *Product Class* | *CEFbase (lbs/kWh)* |
|---|---|
| *Vented Electric, Standard (≥ 4.4 $ft^3$)* | *3.11* |
| *Vented Electric, Compact (120V) (< 4.4 $ft^3$)* | *3.01* |
| *Vented Electric, Compact (240V) (<4.4 $ft^3$)* | *2.73* |
| *Ventless Electric, Compact (240V) (<4.4 $ft^3$)* | *2.13* |
| *Vented Gas* | *2.84*[386] |

*CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.*[387] *If product class unknown, assume electric, standard.*

| *Product Class* | *CEFeff (lbs/kWh)* |
|---|---|
| *Vented or Ventless Electric, Standard (≥ 4.4 $ft^3$)* | *3.93* |
| *Vented or Ventless Electric, Compact (120V) (< 4.4 $ft^3$)* | *3.80* |
| *Vented Electric, Compact (240V) (< 4.4 $ft^3$)* | *3.45* |
| *Ventless Electric, Compact (240V) (< 4.4 $ft^3$)* | *2.68* |
| *Vented Gas* | *3.48*[388] |

*Ncycles = Number of dryer cycles per year*

*= 311 cycles per year.*[389]

*%Electric = The percent of overall savings coming from electricity*

| *Clothes Dryer Fuel Type* | *%Electric* [390] |
|---|---|
| *Electric* | *100%* |
| *Gas* | *16%* |

| Product Class | Algorithm | ΔkWh |
|---|---|---|
| *Vented or Ventless Electric, Standard (≥ 4.4 $ft^3$)* | = ((8.45/3.11 – 8.45/3.93) * 311 * 100%) | 176.3 |
| *Vented or Ventless Electric, Compact (120V) (< 4.4 $ft^3$)* | = ((3/3.01 – 3/3.80) * 311 * 100%) | 64.4 |
| *Vented Electric, Compact (240V) (< 4.4 $ft^3$)* | = ((3/2.73 – 3/3.45) * 311 * 100%) | 71.3 |

---

[386] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

[387] ENERGY STAR Clothes Dryers Key Product Criteria. https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers

[388] Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

389 Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014.

[390] %Electric accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 16% was determined using a ratio of the electric to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

| | | |
|---|---|---|
| *Ventless Electric, Compact (240V) (< 4.4 $ft^3$)* | = ((3/2.13 – 3/2.68) * 311 * 100%) | 89.9 |
| *Vented Gas* | = ((8.45/2.84 – 8.45/3.48) * 311 * 16%) | 27.2 |

**Summer Coincident Peak kW Savings Algorithm**

ΔkW = ΔkWh/Hours * CF

*Where:*

*ΔkWh = Energy Savings as calculated above*

*Hours = Annual run hours of clothes dryer.*

*=290 hours per year.*[391]

*CF = Summer Peak Coincidence Factor for measure*

*= 2.9%*[392]

| Product Class | Algorithm | ΔkW |
|---|---|---|
| *Vented or Ventless Electric, Standard (≥ 4.4 $ft^3$)* | = 176.3/290 * 0.029 | 0.018 |
| *Vented or Ventless Electric, Compact (120V) (< 4.4 $ft^3$)* | = 64.4/290 * 0.029 | 0.006 |
| *Vented Electric, Compact (240V) (< 4.4 $ft^3$)* | = 71.3/290 * 0.029 | 0.007 |
| *Ventless Electric, Compact (240V) (< 4.4 $ft^3$)* | = 89.9/290 * 0.029 | 0.009 |
| *Vented Gas* | = 27.2/290 * 0.029 | 0.003 |

**Annual Fossil Fuel Savings Algorithm**

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

ΔMMBTU = (Load/CEFbase – Load/CEFeff) * Ncycles * MMBTU_convert * %Gas

*Where:*

*MMBTU_convert = Conversion factor from kWh to MMBTU*

*= 0.003413*

*%Gas = Percent of overall savings coming from gas*

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[391] Assumes average of 56 minutes per cycle based on Ecova, 'Dryer Field Study', Northwest Energy Efficiency Alliance (NEEA) 2014

[392] Consistent with coincidence factor of Clothes Washers; Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36.

| *Clothes Dryer Fuel Type* | *%Gas* [393] |
|---|---|
| *Electric* | *0%* |
| *Gas* | *84%* |

| Product Class | Algorithm | ΔMMBTU |
|---|---|---|
| *Vented or Ventless Electric, Standard (≥ 4.4 $ft^3$)* | n/a | 0 |
| *Vented or Ventless Electric, Compact (120V) (< 4.4 $ft^3$)* | n/a | 0 |
| *Vented Electric, Compact (240V) (< 4.4 $ft^3$)* | n/a | 0 |
| *Ventless Electric, Compact (240V) (< 4.4 $ft^3$)* | n/a | 0 |
| *Vented Gas* | =(8.45/2.84 – 8.45/3.48) * 311 * 0.003413 * 0.84 | 0.49 |

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 14 years[394].

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[393] %Gas accounts for the fact that some of the savings on gas dryers comes from electricity (motors, controls, etc). 84% was determined using a ratio of the gas to total savings from gas dryers given by ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis.

394 Based on an average estimated range of 12-16 years. ENERGY STAR Market & Industry Scoping Report. Residential Clothes Dryers. November 2011. http://www.energystar.gov/ia/products/downloads/ENERGY_STAR_Scoping_Report_Residential_Clothes_Dryers.pdf

# Dehumidifier

**Unique Measure Code(s): RS_AP_TOS_DEHUMID_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the purchase (time of sale) and installation of a portable dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR (Version 5.0) in place of a unit that meets the minimum federal standard efficiency.

### Definition of Baseline Condition

The baseline for this measure is defined as a new dehumidifier that meets the Federal Standard efficiency standards for integrated energy factor effective June 13, 2019 as defined below:

| Capacity (pints/day) | Federal Standard Criteria (L/kWh) |
|---|---|
| ≤25.00 | ≥1.30 |
| 25.01 to 50.00 | ≥1.60 |
| ≥50.01 | ≥2.80 |

### Definition of Efficient Condition

To qualify for this measure, the new dehumidifier must meet the integrated energy factor (IEF) criterion in ENERGY STAR standards version 5.0 effective 10/31/2019[395] as defined below:

| Capacity (pints/day) | ENERGY STAR Criteria (L/kWh) |
|---|---|
| ≤25.00 | ≥1.57 |
| 25.01 to 50.00 | ≥1.80 |
| ≥50.01 | ≥3.30 |

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

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[395] https://www.energystar.gov/products/spec/dehumidifiers_specification_version_4_0_pd

**Annual Energy Savings Algorithm**

$$\Delta kWh = Capacity * 0.473 / 24 * Hours * (1 / (L/kWh\_Base) – 1 / (L/kWh\_Eff))$$

*Where:*

*Capacity = Capacity of the unit (pints/day)*
*0.473 = Constant to convert Pints to Liters*
*24 = Constant to convert Liters/day to Liters/hour*
*Hours = Run hours per year*
*= 1632* [396]
*L/kWh = Liters of water per kWh consumed, as provided in tables above*

Annual kWh results for each capacity class are presented below using the average of the capacity range. If the capacity of installed units is collected, the savings should be calculated using the algorithm. If the capacity is unknown, a default average value is provided:

| | | | | Annual kWh | | |
|---|---|---|---|---|---|---|
| **Capacity (pints/day) Range** | **Capacity Used** | **Federal Standard Criteria (≥ L/kWh)** | **ENERGY STAR Criteria (≥ L/kWh)** | **Federal Standard** | **ENERGY STAR** | **Savings** |
| ≤25 | 20 | 1.30 | 1.57 | 495 | 410 | 85 |
| > 25 to ≤35 | 30 | 1.60 | 1.80 | 603 | 536 | 67 |
| > 35 to ≤50 | 42.5 | 1.60 | 1.80 | 854 | 759 | 95 |
| > 50 to ≤ 75 | 62.5 | 2.80 | 3.30 | 718 | 609 | 109 |
| > 75 to ≤ 185 | 130 | 2.80 | 3.30 | 1493 | 1267 | 226 |
| Average | 57.0 | 2.02 | 2.35 | 908 | 779 | 129 |

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*Hours = Annual operating hours*
*= 1632 hours*[397]

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[396] Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

[397] Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-

*CF* = *Summer Peak Coincidence Factor for measure*
= *0.37* [398]

| Capacity (pints/day) Range | ΔkW |
|---|---|
| ≤25 | 0.019 |
| > 25 to ≤35 | 0.015 |
| > 35 to ≤50 | 0.022 |
| > 50 to ≤ 75 | 0.025 |
| > 75 to ≤ 185 | 0.051 |
| Average | 0.026 |

## Annual Fossil Fuel Savings Algorithm

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 12 years.[399]

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6a8b

[398] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

[399] ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

# Dehumidifier, Early Retirement / Recycling

**Unique Measure Code(s): RS_AP_ERET_DEHUMID_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes the savings resulting from removing an existing, operating dehumidifier from service prior to its natural end of life. The program should target, but not be limited to, dehumidifiers put into service prior to June 2019. If primary data indicate the unit is replaced rather than retired, savings should be based on the Dehumidifier Time-of-Sale measure. If rate of replacement is not tracked by the utility programs, see below.

### Definition of Baseline Condition

The baseline condition is the existing inefficient dehumidifier.

### Definition of Efficient Condition

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

### Energy Savings Algorithm

Remaining life kWh savings =

$$Capacity\ x\frac{.473}{24}\ x\ hours\ x\frac{1}{L\ per\ kWh}\ x\ (Service\ Life - Existing\ Age)$$

*Where:*

*Capacity = Capacity of the unit (pints/day)*
*0.473 = Constant to convert Pints to Liters*
*24 = Constant to convert Liters/day to Liters/hour*
*Hours = Run hours per year*
*= 1632*[400]
*L/kWh = Liters of water per kWh consumed, as provided in table below. Values reflect a manufacture date range that coincides with timing of federal efficiency standards.*
*Service Life = 12*
*Existing Age = age of existing unit*

Annual kWh savings results for each capacity class are presented in the table below reflecting two recent federal standards as baseline. If the capacity of installed units is collected, the savings should be calculated using the algorithm. If the capacity is unknown, a default average value is provided. If the unit being removed is ENERGY STAR labeled, custom calculation will be required.

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[400] Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

| | | | | Annual kWh Savings | |
|---|---|---|---|---|---|
| Capacity (pints/day) Range | Capacity of existing unit | 2007 Federal Standard (≥ L/kWh)[401] | 2012 Federal Standard (≥ L/kWh)[402] | Mfr date before Oct 2012 | Mfr date between Nov 2012 and June 2019 |
| ≤25 | 20 | 1 | 1.35 | 643 | 477 |
| > 25 to ≤35 | 30 | 1.2 | 1.35 | 804 | 715 |
| > 35 to ≤45 | 40 | 1.3 | 1.5 | 990 | 858 |
| > 45 to ≤ 54 | 50 | 1.3 | 1.6 | 1237 | 1005 |
| > 54 to ≤ 75 | 65 | 1.5 | 1.7 | 1394 | 1230 |
| > 75 to ≤ 185 | 130 | 2.25 | 2.5 | 1858 | 1673 |
| Average | 56 | 1.43 | 1.67 | 1260 | 1077 |

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta \mathrm{kW} = \frac{\Delta \mathrm{kWh}}{Hours} \mathrm{x\ CF}$$

*Where:*

*kWh = annual kWh savings*
*Hours = Annual operating hours*
*= 1632 hours*[403]
*CF = Summer Peak Coincidence Factor for measure*
*= 0.37* [404]

| Capacity (pints/day) Range | ΔkW before 2012 | ΔkW 2012-2019 |
|---|---|---|
| ≤25 | 0.146 | 0.108 |
| > 25 to ≤35 | 0.182 | 0.162 |

---

[403] Based on 68 days of 24-hour operation; ENERGY STAR Dehumidifier Calculator https://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

[404] Assume usage is evenly distributed day vs. night, weekend vs. weekday and is used between April through the end of September (4392 possible hours). 1632 operating hours from ENERGY STAR Dehumidifier Calculator. Coincidence peak during summer peak is therefore 1632/4392 = 37.2%

| | | |
|---|---|---|
| > 35 to ≤45 | 0.224 | 0.194 |
| > 45 to ≤ 54 | 0.280 | 0.228 |
| > 54 to ≤ 75 | 0.316 | 0.279 |
| > 75 to ≤ 185 | 0.421 | 0.379 |
| Average | 0.262 | 0.225 |

If rate of replacement is not tracked by the utility programs, assume 80% of dehumidifiers recycled through the program are subsequently replaced. For example, if a 50 pint/day dehumidifier is recycled, savings are:

$$kWh\ Saved = (1{,}237\ kWh\ \times 20\%) + \big((1237\ kWh - 1005\ kWh)\ \times\ 80\%\big) = 433\ kWh$$

The first term of the equation follows the dehumidifier recycling measure, assuming no replacement for 20% of recycled dehumidifiers. The second term represents the savings from replacing the in-situ unit with a federal standard unit. For purposes of cost-effectiveness, the same replacement fraction should be assumed in calculating incremental costs.

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

n/a

# ENERGY STAR Air Purifier/Cleaner

**Unique Measure Code(s): RS_AP_TOS_AIRPUR_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

An air purifier (cleaner) is a portable electric appliance that removes dust and fine particles from indoor air. This measure characterizes the purchase and installation of a unit meeting the efficiency specifications of ENERGY STAR in place of a baseline model.

### Definition of Baseline Condition

The baseline equipment is assumed to be a conventional non-ENERGY STAR unit with baseline efficiency estimates of 1.0 CADR/Watt based upon EPA research on available models, 2011[405].

### Definition of Efficient Condition

The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below. [406]

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust[407] to be considered under this specification.
- Minimum Performance Requirement: = 2.0 CADR/Watt (Dust)
- Standby Power Requirement: = 2.0 Watts Qualifying models that perform secondary consumer functions (e.g. clock, remote control) must meet the standby power requirement.
- UL Safety Requirement: Models that emit ozone as a byproduct of air cleaning must meet UL Standard 867 (ozone production must not exceed 50ppb)

ENERGY STAR has published a new specification (version 2.0) for these products that takes effect July 7, 2020.[408] A comparison of the average efficiency levels expected under the version 2.0 specification and the version 1.2 specification are provided as part of the Final Version 2.0 Data Package:[409]

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[405] ENERGY STAR Appliance Savings Calculator; no longer available online. Calculator assumed 16 hours of operation daily, 365 days a year. Baseline efficiency was deemed as 1.0 CADR/watt, with 1.0 watts of standby power. The ENERGY STAR v1.2 efficiency was deemed as 1.0 CADR/watt and 0.6 watts of standby power.

[406] ENERGY STAR Room Air Cleaners Program Requirements, v1.2. https://www.energystar.gov/sites/default/files/Room_Air_Cleaners_Program_Requirements%20V1.2.pdf

[408] ENERGY STAR Room Air Cleaners Program Requirements, v2.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%202.0%20Final%20Room%20Air%20Cleaners%20Program%20Requirements.pdf

[409] ENERGY STAR Room Air Cleaners Final Version 2.0 Data Package. Incremental Cost and Payback worksheet. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V2%20Room%20Air%20Cleaners%20Data%20Package.xlsx

| Product Size | Efficiency Level | Smoke CADR/W |
|---|---|---|
| 30 ≤ Smoke CADR < 100 | ENERGY STAR V1.2 | 1.72 |
| | ENERGY STAR V2.0 | 1.90 |
| 100 ≤ Smoke CADR < 150 | ENERGY STAR V1.2 | 1.91 |
| | ENERGY STAR V2.0 | 2.40 |
| 150 ≤ Smoke CADR < 200 | ENERGY STAR V1.2 | 2.02 |
| | ENERGY STAR V2.0 | 2.90 |
| 200 ≤ Smoke CADR | ENERGY STAR V1.2 | 1.97 |
| | ENERGY STAR V2.0 | 2.90 |

**Annual Energy Savings Algorithm**

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

Where:

$kWh_{BASE}$ = Baseline kWh consumption per year[410]

= see tables below

$kWh_{ESTAR}$ = ENERGY STAR kWh consumption per year[411]

= see tables below

**Through July 6, 2020:**

| Clean Air Delivery Rate (CADR) | CADR used in calculation | Baseline Unit Energy Consumption (kWh/year) | ENERGY STAR Unit Energy Consumption (kWh/year) | ΔkWH |
|---|---|---|---|---|
| CADR 51-100 | 75 | 441 | 148 | 293 |
| CADR 101-150 | 125 | 733 | 245 | 488 |
| CADR 151-200 | 175 | 1025 | 342 | 683 |
| CADR 201-250 | 225 | 1317 | 440 | 877 |
| CADR Over 250 | 275 | 1609 | 537 | 1072 |

---

[410] Based on assumptions found in the ENERGY STAR Appliance Savings Calculator; Efficiency 1.0 CADR/Watt, 16 hours a day, 365 days a year and 1W standby power.

[411] Ibid. Efficiency 3.0 CADR/Watt, 16 hours a day, 365 days a year and 0.6W standby power.

**Beginning July 7, 2020:**[412]

| Clean Air Delivery Rate (CADR) | ΔkWH |
|---|---|
| 30 ≤ Smoke CADR < 100 | 39 |
| 100 ≤ Smoke CADR < 150 | 95 |
| 150 ≤ Smoke CADR < 200 | 173 |
| 200 ≤ Smoke CADR | 328 |

### Summer Coincident Peak kW Savings Algorithm

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

Where:

ΔkWh = Gross customer annual kWh savings for the measure

Hours = Average hours of use per year

= 5840 hours[413]

CF = Summer Peak Coincidence Factor for measure

= 0.67[414]

| Clean Air Delivery Rate | ΔkW |
|---|---|
| CADR 51-100 | 0.034 |
| CADR 101-150 | 0.056 |
| CADR 151-200 | 0.078 |
| CADR 201-250 | 0.101 |
| CADR Over 250 | 0.123 |

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

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[412] ENERGY STAR Room Air Cleaners Final Version 2.0 Data Package. Energy and Cost Savings worksheet. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V2%20Room%20Air%20Cleaners%20Data%20Package.xlsx

413 Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator; 16 hours a day, 365 days a year.

[414] Assumes appliance use is equally likely at any hour of the day or night.

## Measure Life

The measure life is assumed to be 9 years[415].

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[415] ENERGY STAR Appliance Savings Calculator; Based on Appliance Magazine, Portrait of the U.S. Appliance Industry 1998.

# Dishwasher

**Unique Measure Code(s): RS_AP_TOS_DISHWAS_0415**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

A dishwasher meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard. This measure is only for standard dishwashers, not compact dishwashers. A compact dishwasher is a unit that holds less than eight place settings with six serving pieces.

### Definition of Baseline Condition

The baseline for this measure is defined as a new dishwasher that meets the Federal Standard efficiency standards as defined below[416]:

| Dishwasher Type | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|
| Standard | 307 | 5.0 |

### Definition of Efficient Condition

To qualify for this measure, the new dishwasher must meet the ENERGY STAR standards version 6.0 as defined below:

| Dishwasher Type | Maximum kWh/year | Maximum gallons/cycle |
|---|---|---|
| Standard | 270 | 3.50 |

### Annual Energy Savings Algorithm

$\Delta$kWh[417] = (($kWh_{Base}$ - $kWh_{ESTAR}$) * (%kWh_op + (%kWh_heat * %Electric_DHW )))

*Where:*

*$kWh_{BASE}$ = Baseline kWh consumption per year*

*= 307 kWh*

*$kWh_{ESTAR}$ = ENERGY STAR kWh annual consumption = 270*

*%kWh_op = Percentage of dishwasher energy consumption used for unit operation*

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[416] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67

[417] The Federal Standard and ENERGY STAR annual consumption values include electric consumption for both the operation of the machine and for heating the water that is used by the machine.

*= 1 - 56%*[418]

*= 44%*

*%kWh_heat = Percentage of dishwasher energy consumption used for water heating*

*= 56%*[419]

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

| *DHW fuel* | *%Electric_DHW* |
|---|---|
| *Electric* | *100%* |
| *Natural Gas* | *0%* |
| *Unknown* | *65%*[420] |

| DHW Fuel | Algorithm | ΔkWh |
|---|---|---|
| Electric | = ((307 - 270) * (0.44 + (0.56 * 1.0))) | 37 |
| Unknown | = ((307 - 270) * (0.44 + (0.56 * 0.65))) | 29.7 |

### Summer Coincident Peak kW Savings Algorithm

ΔkW = ΔkWh/Hours * CF

*Where:*

*Hours = Annual operating hours*[421]

*= 210 hours*

*CF = Summer Peak Coincidence Factor*

*= 2.6%* [422]

| DHW Fuel | Algorithm | ΔkW |
|---|---|---|
| Electric | = 37/210 * 0.026 | 0.0046 |

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[418] ENERGY STAR Dishwasher Calculator, see 'EnergyStarCalculatorConsumerDishwasher.xls'.

[419] Ibid.

[420] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the Mid-Atlantic region.

[421] Assuming one and a half hours per cycle and 140 cycles per year therefore 210 operating hours per year; 140 cycles per year is based on a weighted average of dishwasher usage in Mid-Atlantic region derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

[422] Based on 8760 end use data for Missouri, provided to VEIC by Ameren for use in the Illinois TRM. The average DW load during peak hours is divided by the peak load. In the absence of a Mid Atlantic specific loadshape this is deemed a reasonable proxy since loads would likely be similar.

| | | |
|---|---|---|
| Unknown | = 29.75/210 * 0.02 | 0.0037 |

**Annual Fossil Fuel Savings Algorithm**

ΔMMBTU = $(kWh_{Base} - kWh_{ESTAR})$ * %kWh_heat * %Natural Gas_DHW * R_eff * 0.003413

*Where*

*%kWh_heat = % of dishwasher energy used for water heating*

*= 56%*

*%Natural Gas_DHW = Percentage of DHW savings assumed to be Natural Gas*

| *DHW fuel* | *%Natural Gas_DHW* |
|---|---|
| *Electric* | *0%* |
| *Natural Gas* | *100%* |
| *Unknown* | *35%*[423] |

*R_eff = Recovery efficiency factor*

*= 1.31*[424]

*0.003413 = factor to convert from kWh to MMBTU*

| ENERGY STAR Specification | DHW Fuel | Algorithm | ΔMMBTU |
|---|---|---|---|
| 6.0 | Gas | = (307 - 270) * 0.56 * 1.0 * 1.31 * 0.003413 | 0.09 |
| 6.0 | Unknown | = (307 - 270) * 0.56 * 0.35 * 1.31 * 0.003413 | 0.03 |

**Annual Water Savings Algorithm**

ΔCCF = $(Water_{Base} - Water_{EFF})$ * GalToCCF

---

[423] Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for South Region, data for the states of Delaware, Maryland, West Virginia and the District of Columbia. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographic area, then that should be used.

[424] To account for the different efficiency of electric and Natural Gas water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.75 used to account for older existing units)), and electric water heater with 0.98 recovery efficiency (http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/Waste_Water_Heat_Recovery_Guidelines.pdf ). Therefore, a factor of 0.98/0.75 (1.31) is applied.

*Where*

*$Water_{Base}$ = annual water consumption of conventional unit*

*= 700 gallons*[425]

*$Water_{EFF}$ = annual water consumption of efficient unit:*

| ENERGY STAR Specification | WaterEFF (gallons) |
|---|---|
| 6.0 | 490[426] |

GalToCCF = factor to convert from gallons to CCF

= 0.001336

| ENERGY STAR Specification | Algorithm | ΔCCF |
|---|---|---|
| 6.0 | = (700 – 490) * 0.001336 | 0.28 |

**Measure Life**

The measure life is assumed to be 10 years[427].

---

[425] Assuming 5 gallons/cycle (maximum allowed) and 140 cycles per year based on a weighted average of dishwasher usage in the Mid-Atlantic Region derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

[426] Assuming 3.50 gallons/cycle (maximum allowed) and 140 cycles per year based on a weighted average of dishwasher usage in the Mid-Atlantic Region derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

[427] ENERGY STAR Dishwasher Calculator, see ‘EnergyStarCalculatorConsumerDishwasher.xls’.

*Pool Pump End Use*

# Pool pump-two speed

## Unique Measure Code: RS_PP_TOS_PPTWO_0711
## Effective Date: June 2014
## End Date: TBD

### Measure Description

This measure describes the purchase of a two speed swimming pool pump capable of running at 50% speed and being run twice as many hours to move the same amount of water through the filter. The measure could be installed in either an existing or new swimming pool. The installation is assumed to occur during a natural time of sale.

### Definition of Baseline Condition

The baseline condition is a standard efficiency, 1.36 kW electric pump operating 5.18 hours per day.

### Definition of Efficient Condition

The efficient condition is an identically sized two speed pump operating at 50% speed (50% flow) for 10.36 hours per day.

### Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Two\ Speed}$$ [428]

*Where:*

$kWh_{Base}$ = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= *707 kWh*

$kWh_{Two\ Speed}$ = *typical consumption for an efficient two speed pump motor*
= *177 kWh*

$$\Delta kWh = 707 - 177$$

$$= 530\ kWh$$

### Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [429]

*Where:*

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[428] 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

[429] 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

$kW_{Base}$ = *Connected load of baseline motor*
*= 1.36 kW*
$kW_{Two\ Speed}$ = *Connected load of two speed motor = 0.171 kW*
$CF_{SSP}$ = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*
*= 0.20*[430]
$CF_{PJM}$ = *PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
*= 0.27*[431]

$$\Delta kW_{SSP} = (1.36 - 0.171) * 0.20$$

$$= 0.24 \text{ kW}$$

$$\Delta kW_{SSP} = (1.36 - 0.171) * 0.27$$

$$= 0.32 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 10 yrs[432].

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[430] Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16
[431] Ibid.
[432] VEIC estimate.

# Pool pump-variable speed

**Unique Measure Code: RS_PP_TOS_PPVAR_0711**
**Effective Date: June 2014**
**End Date: TBD**

### Measure Description

This measure describes the purchase of a variable speed swimming pool pump capable of running at 40% speed and being run two and a half times as many hours to move the same amount of water through the filter. The measure could be installed in either an existing or new swimming pool. The installation is assumed to occur during a natural time of sale.

### Definition of Baseline Condition

The baseline condition is a standard efficiency, 1.36 kW electric pump operating 5.18 hours per day.

### Definition of Efficient Condition

The efficient condition is an identically sized variable speed pump operating at 40% flow for 13 hours per day.

### Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{Base} - kWh_{Variable\ Speed}$$ [433]

*Where:*

$kWh_{Base}$ = *typical consumption of a single speed motor in a cool climate (assumes 100 day pool season)*
= *707 kWh*

$kWh_{Variable\ Speed}$ = *typical consumption for an efficient variable speed pump motor*
= *113 kWh*

$$\Delta kWh = 707 - 113$$

$$= 594\ kWh$$

### Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = (kW_{Base} - kW_{Two\ Speed}) * CF$$ [434]

*Where:*

$kW_{Base}$ = *Connected load of baseline motor*
= *1.36 kW*

---

[433] 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

[434] 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

$kW_{Two\ Speed}$ = *Connected load of variable speed motor*
= *0.087 kW*

$CF_{SSP}$ = *Summer System Peak Coincidence Factor for pool pumps (hour ending 5pm on hottest summer weekday)*
= *0.20*[435]

$CF_{PJM}$ = *PJM Summer Peak Coincidence Factor for pool pumps (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
= *0.27*[436]

$$\Delta kW_{SSP} = (1.36 - 0.087) * 0.20$$

$$= 0.25\ kW$$

$$\Delta kW_{SSP} = (1.36 - 0.087) * 0.27$$

$$= 0.34\ kW$$

## Annual Fossil Fuel Savings Algorithm

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 10 yrs[437].

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

[436] Ibid.

[437] VEIC estimate.

*Plug Load End Use*

# Advanced Power Strip

**Unique Measure Code: RS_PL_TOS_APS_0420**
**Effective Date: April 2020**
**End Date: TBD**

## Measure Description

There are two types of APS: Tier 1 and Tier 2.

Tier 1 APS have a master control socket arrangement and will shut off the items plugged into the controlled power-saver sockets when they sense that the appliance plugged into the master socket has been turned off. Conversely, the appliance plugged into the master control socket has to be turned on and left on for the devices plugged into the power-saver sockets to function.

Tier 2 APS deliver additional functionality beyond that of a Tier 1 unit, as Tier 2 units manage both standby and active power consumption. The Tier 2 APS manage standby power consumption by turning off devices from a control event; this could be a TV or other item powering off, which then powers off the controlled outlets to save energy. Active power consumption is managed by the Tier 2 unit by monitoring a user's engagement or presence in a room by either or both infrared remote signals sensing or motion sensing. If after a period of user absence or inactivity, The Tier 2 unit will shut off all items plugged into the controlled outlets, thus saving energy. There are two types of Tier 2 APS available on the market. Tier 2 Infrared (IR) detect signals sent by remote controls to identify activity, while Tier 2 Infrared-Occupancy Sensing (IR-OS) use remote signals as well as an occupancy sensing component to detect activity and sense for times to shut down. Due to uncertainty surrounding the differences in savings for each technology, the Tier 2 savings are blended into a single number.

## 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 Tier 1 or Tier 2 Advanced Power Strip.

## Annual Energy Savings Algorithm

The energy savings and demand reduction for Tier 1 and Tier 2 APS outlets are obtained from several recently conducted field studies, with the savings estimates applied to measured in-service rates (ISR) and realization rates (RR) to determine final savings.

The energy savings and demand reduction are calculated for both home office and home entertainment use for Tier 1 strips, and only for home entertainment use for Tier 2 strips.[438] For Tier 1 strips, if the intended use of the power strip is not specified, or if multiple power strips are

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[438] Tier 2 strips are typically installed only in home entertainment center applications.

purchased, the values for “unspecified use” should be applied. If it is known that the power strip is intended to be used for an entertainment center, the “entertainment center” values should be applied, while the “home office” values should be applied if it is being used in a home office setting. For Tier 2 strips, the end use is assumed to be a home entertainment center and the savings vary based on the type of Tier 2 strip, IR, IR-OS, or unspecified.

$\Delta kWh \quad = Annual\_kWh \times ERP_{energy\_}$

*Where:*

**Energy Values for Advanced Power Strips**[439]

| APS Type | Location | Annual kWh | $ERP_{energy}$ | kWh savings |
|---|---|---|---|---|
| Tier 1 | Home entertainment system | 471 | 27% | 100.6 |
| Tier 1 | Home office | 399 | 21% | 66.3 |
| Tier 1 | Unspecified end-use[440] | 449 | 25% | 112.3 |
| Tier 2 | Home entertainment system | 471 | 44% | 141.1 |

### Summer Coincident Peak kW Savings Algorithm

$\Delta kW \quad = Load \times ERP_{peak,}$

**Demand Values for Advanced Power Strips**[441]

| APS Type | Location | Load | $ERP_{peak}$ | kW Reduction |
|---|---|---|---|---|
| Tier 1 | Home entertainment system | 0.058 | 20% | 0.010 |
| Tier 1 | Home office | 0.038 | 18% | 0.007 |
| Tier 1 | Unspecified end-use[442] | 0.052 | 19% | 0.010 |
| Tier 2 | Home entertainment system | 0.058 | 41% | 0.024 |

---

[439] “RLPNC 17-3: Advanced Power Strip Metering Study,” Massachusetts Programs Administrators and EEAC, (Mar. 2019), http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_173_APSMeteringReport_Revised_18March2019.pdf. Table 49: APS Impact Factors.

[440] Note that this was based on the MA RPLNC 173 APS Metering Study that determined Tier 1 APS to be used in home entertainment settings 69% of the time, and 31% in home office environments.

[441] “RLPNC 17-3: Advanced Power Strip Metering Study,” Massachusetts Programs Administrators and EEAC, (Mar. 2019), http://ma-eeac.org/wordpress/wp-content/uploads/RLPNC_173_APSMeteringReport_Revised_18March2019.pdf. Table 49: APS Impact Factors.

[442] Note that this was based on the MA RPLNC 173 APS Metering Study that determined Tier 1 APS to be used in home entertainment settings 69% of the time, and 31% in home office environments.

## Annual Fossil Fuel Savings Algorithm

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 5 years[443].

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[443] California Public Utilities Commission Database for Energy Efficient Resources (DEER) EUL Support Table for 2020, http://www.deeresources.com/files/DEER2020/download/SupportTable-EUL2020.xlsx. Accessed December 2018. Via PA TRM.

*Retail Products*

# ENERGY STAR Soundbar

## Unique Measure Code(s): RS_PL_TOS_RPPSND_0616

## Effective Date: June 2016

## End Date: TBD

### Measure Description

This measure relates to the upstream promotion of residential soundbar meeting the ENERGY STAR criteria through the Energy Star Retail Products Program. This measure assumes a more stringent requirement than ENERGY STAR Version 3.0.[444]

### Definition of Baseline Condition

The baseline condition is assumed to be a standard soundbar.

### Definition of Efficient Condition

The RPP offers two tiers of incentives for this product – ENERGY STAR + 15% and ENERGY STAR +50% soundbar. Savings for both measures are given below. They were developed by decreasing the power requirements and increasing the efficiency requirements by the appropriate amount.

### Annual Energy Savings Algorithm[445]

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*

$kWh_{base}$ = *Baseline unit energy consumption*
= *Assumed to be 69 kWh/year*[446]
$kWh_{eff}$ = *Efficient unit energy consumption*
= *Assumed to be 25 kWh/year*[447] *for the ENERGY STAR +50% Tier and 42.5 kWh/ year for the ENERGY STAR +15% Tier.*

### Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0.0005$$[448]

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[444] http://www.energystar.gov/sites/default/files/Final%20Version%203.0%20AV%20Program%20Requirements%20%28Rev%20Dec-2014%29.pdf

[445] Energy Savings from this measure are derived from Energy Star estimates. See 'RPP Product Analysis 9-23-15.xlsx'

[446] The baseline unit energy consumption is based on information provided from a Fraunhofer Center for Sustainable Energy System study, titled Energy Consumption of Consumer Electronics in US Households, 2013, available at: http://www.ce.org/CorporateSite/media/Government-Media/Green/Energy-Consumption-of-CE-in-U-S-Homes-in-2010.pdf.

[447] Due to the high market penetration of ENERGY STAR certified soundbars, a weighted average of the unit energy consumption of both non-ENERGY STAR and ENERGY STAR models was calculated in order to accurately provide savings estimates for the market in 2016.

[448] Wattage difference between base and efficient sound bars when in sleep mode

## Annual Fossil Fuel Savings Algorithm

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The expected measure life is assumed to be 7 years.[449]

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[449] ENERGY STAR assumes a 7-year useful life.

# ENERGY STAR Office Equipment

**Unique Measure Code(s): RS_PL_TOS_OE_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the upstream promotion of desktop computers, monitors, laptop computers, fax machines, copiers and multifunction devices meeting the ENERGY STAR Eligibility Criteria Version 6.1.

### Definition of Baseline Condition

The baseline condition is assumed to be standard equipment of the same nature used in a residential setting.

### Definition of Efficient Condition

The efficient condition is ENERGY STAR equipment meeting the Eligibility Criteria Version 6.1 and used in a residential setting.

### Annual Energy Savings Algorithm

The measurement of energy savings is based on a deemed savings value multiplied by the quantity of the measure.

Total kWh Savings = Number of Units x Savings per Unit

*Where:*

| Measure | | Energy Savings (ESav, kWh)[450] |
|---|---|---|
| **Computer (Desktop)** | | 119 |
| **Computer (Laptop)** | | 22 |
| **Fax Machine (laser)** | | 16 |
| **Copier (monochrome)** | ≤ 5images/min | 37 |
| | 5 < images/min ≤ 15 | 26 |
| | 15 < images/min ≤ 20 | 10 |
| | 20 < images/min ≤ 30 | 42 |
| | 30 < images/min ≤ 40 | 50 |

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[450] ENERGY STAR Office Equipment Calculator http://www.energystar.gov/sites/default/files/asset/document/Office%20Equipment%20Calculator.xlsx (Referenced latest version released in October 2016). Default values were used. Using a commercial office equipment load shape, the percentage of total savings that occur during the PJM peak demand period was calculated and multiplied by the energy savings. As of December 1, 2018, the published ENERGY STAR Office Equipment Calculator does not reflect the current specification for computers (ENERGY STAR® Program Requirements Product Specification for Computers Eligibility Criteria Version 7.1). V7.1 introduced modest improvements to both desktop and laptop computer efficiency. As a result, the savings values for computers presented in this measure entry reflect savings for V6-compliant models. This characterization should be updated when an updated ENERGY STAR Office Equipment Calculator becomes available. (via PA TRM)

| | | |
|---|---|---|
| | 40 < images/min ≤ 65 | 181 |
| | 65 < images/min ≤ 82 | 372 |
| | 82 < images/min ≤ 90 | 469 |
| | > 90 images/min | 686 |
| **Printer (laser, monochrome)** | ≤ 5 images/min | 37 |
| | 5 < images/min ≤ 15 | 26 |
| | 15 < images/min ≤ 20 | 24 |
| | 20 < images/min ≤ 30 | 42 |
| | 30 < images/min ≤ 40 | 50 |
| | 40 < images/min ≤ 65 | 181 |
| | 65 < images/min ≤ 82 | 372 |
| | 82 < images/min ≤ 90 | 542 |
| | > 90 images/min | 686 |
| **Printer (Ink Jet)** | | 6 |
| **Multifunction Device (laser, monochrome)** | ≤ 5 images/min | 57 |
| | 5 < images/min ≤ 10 | 48 |
| | 10 < images/min ≤ 26 | 52 |
| | 26 < images/min ≤ 30 | 93 |
| | 30 < images/min ≤ 50 | 248 |
| | 50 < images/min ≤ 68 | 420 |
| | 68 < images/min ≤ 80 | 597 |
| | > 80 images/min | 764 |
| **Multifunction Device (Ink Jet)** | | 6 |
| **Monitor** | | 24 |

### Summer Coincident Peak kW Savings Algorithm

The measurement of demand savings is based on a deemed savings value multiplied by the quantity of the measure.

*Where:*

| **Measure** | | **Demand Savings (DSav, kW)**[451] |
|---|---|---|
| **Computer (Desktop)** | | 0.0161 |
| **Computer (Laptop)** | | 0.0030 |
| **Fax Machine (laser)** | | 0.0022 |
| **Copier (monochrome)** | ≤ 5images/min | 0.0050 |
| | 5 < images/min ≤ 15 | 0.0035 |
| | 15 < images/min ≤ 20 | 0.0011 |
| | 20 < images/min ≤ 30 | 0.0057 |

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[451] ENERGY STAR Office Equipment Calculator (via PA TRM)

| | | |
|---|---|---|
| | 30 < images/min ≤ 40 | 0.0068 |
| | 40 < images/min ≤ 65 | 0.0244 |
| | 65 < images/min ≤ 82 | 0.0502 |
| | 82 < images/min ≤ 90 | 0.0633 |
| | > 90 images/min | 0.0926 |
| **Printer (laser, monochrome)** | ≤ 5 images/min | 0.0050 |
| | 5 < images/min ≤ 15 | 0.0035 |
| | 15 < images/min ≤ 20 | 0.0031 |
| | 20 < images/min ≤ 30 | 0.0057 |
| | 30 < images/min ≤ 40 | 0.0068 |
| | 40 < images/min ≤ 65 | 0.0244 |
| | 65 < images/min ≤ 82 | 0.0502 |
| | 82 < images/min ≤ 90 | 0.0732 |
| | > 90 images/min | 0.0926 |
| **Printer (Ink Jet)** | | 0.0008 |
| **Multifunction Device (laser, monochrome)** | ≤ 5 images/min | 0.0077 |
| | 5 < images/min ≤ 10 | 0.0065 |
| | 10 < images/min ≤ 26 | 0.0070 |
| | 26 < images/min ≤ 30 | 0.0126 |
| | 30 < images/min ≤ 50 | 0.0335 |
| | 50 < images/min ≤ 68 | 0.0567 |
| | 68 < images/min ≤ 80 | 0.0806 |
| | > 80 images/min | 0.1031 |
| **Multifunction Device (Ink Jet)** | | 0.0008 |
| **Monitor** | | 0.0032 |

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The expected measure life is as follows[452]:

Computer: 4 years

Monitor: 4 years

Fax: 4 years

Printer: 5 years

Copier: 6 years

Multifunction Device: 6 years

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[452] ENERGY STAR Office Equipment Calculator

# ENERGY STAR Television

**Unique Measure Code(s): RS_PL_TOS_RPPSTV_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the upstream promotion of monitors meeting the ENERGY STAR Television Eligibility Criteria Version 7.0.

### Definition of Baseline Condition

The baseline condition is assumed to be a standard television used in a residential setting.

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR television meeting the current Eligibility Criteria Version 7.0 and used in a residential setting.[453]

### Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*

$kWh_{base}$ = *Baseline unit energy consumption varies by diagonal screen size.*[454]

| Diagonal screen size | Conventional | ENERGY STAR |
|---|---|---|
| 20" and under | 45 | 30 |
| 21" - 23" | 48 | 39 |
| 24" - 29" | 55 | 41 |
| 30" - 34" | 66 | 49 |
| 35" - 39" | 85 | 62 |
| 40" - 44" | 101 | 71 |
| 45" - 49" | 128 | 85 |
| 50" - 54" | 137 | 97 |
| 55" - 59" | 161 | 106 |
| 60" - 64" | 162 | 122 |
| 65" or greater | 295 | 137 |

$kWh_{eff}$ = *Efficient unit energy consumption varies by diagonal screen size. See above.*

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[453] https://www.energystar.gov/sites/default/files/FINAL%20Version%207.0%20Television%20Program%20Requirements%20%28Dec-2014%29_0.pdf

[454] ENERGY STAR Consumer Electronics Calculator. October 2016.

### Summary Coincident Peak kW Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff} \times CF$$

*Where:*

$kWh_{base}$ = *Baseline unit wattage varies by diagonal screen size:*

| Diagonal screen size | Conventional | ENERGY STAR |
|---|---|---|
| 20" and under | 23 | 15 |
| 21" - 23" | 25 | 20 |
| 24" - 29" | 29 | 21 |
| 30" - 34" | 35 | 26 |
| 35" - 39" | 46 | 33 |
| 40" - 44" | 54 | 37 |
| 45" - 49" | 69 | 45 |
| 50" - 54" | 74 | 52 |
| 55" - 59" | 87 | 57 |
| 60" - 64" | 88 | 66 |
| 65" or greater | 160 | 74 |

$kWh_{eff}$ = *Efficient unit wattage varies by diagonal screen size. See above.*

$CF$ = *21%*[455]

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Incremental Cost

The incremental cost for this time of sale measure is $0.[456]

### Measure Life

The expected measure life is assumed to be 6 years.[457]

### Operation and Maintenance Impacts

n/a

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[455] Estimate based on On-mode hours per day (5 hours/day) as a percentage of all hours.

[456] A zero incremental cost is supported by two sources. Efficiency Vermont. Technical Reference User Manual (TRM). March 16, 2015. Efficient Television measure has an incremental cost of $0. The Appliance Standards Awareness Project assumes an incremental cost of $0 for an appliance standard based on a prior version of the ENERGY STAR specification. https://appliance-standards.org/product/televisions. .

[457] ENERGY STAR Consumer Electronics Calculator.

# ENERGY STAR Most Efficient Television

**Unique Measure Code(s): RS_PL_TOS_ESTVMOST_0520**
**Effective Date: May 2020**
**End Date: TBD**

### Measure Description

This measure relates to the promotion of televisions meeting the 2020 ENERGY STAR Most Efficient Television Recognition Criteria.

### Definition of Baseline Condition

The baseline condition is assumed to be a television used in a residential setting meeting the prior version (7.0) of the ENERGY STAR Eligibility Criteria.[458]

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR Most Efficient television meeting the 2020 Most Efficient Recognition Criteria and used in a residential setting.[459]

### Annual Energy Savings Algorithm

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*

$kWh_{base}$ = *Baseline unit On Mode energy consumption varies by diagonal screen size.*[460]

$kWh_{eff}$ = *Efficient unit On Mode energy consumption varies by diagonal screen size.*

Passive (Stand by) consumption is ignored in the following calculations as it only compromises 2 kWh a year for a baseline TV operating 19 hours a day, regardless of screen size

From the ENERGY STAR Most Efficient TV Recognition Criteria, a qualifying TV's maximum energy consumption is defined by:

$$P_{on\_max} = 66 \times tanh[0.000412\, x\, (A - 140) + 0.014\,] + 14$$

*Where:*

- $P_{on\_max}$ is the maximum allowable On Mode Power consumption in Watts.
- A is the viewable screen area of the product in sq. inches, where:

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[458] https://www.energystar.gov/sites/default/files/FINAL%20Version%207.0%20Television%20Program%20Requirements%20%28Dec-2014%29_0.pdf

[459] https://www.energystar.gov/sites/default/files/Televisions%20ENERGY%20STAR%20Most%20Efficient%202020%20Final%20Criteria.pdf

[460] ENERGY STAR Consumer Electronics Calculator. October 2016.

A = 0.43 x Diagonal screen size$^2$

- tanh is the hyperbolic tangent function

| Television Energy Use and Savings by Screen Size | | | |
|---|---|---|---|
| Diagonal screen size | Conventional | Most Efficient | kWh Savings |
| 20" and under | 28.1 | 28.0 | 0.1 |
| 21" - 23" | 37.0 | 30.6 | 6.4 |
| 24" - 29" | 38.3 | 35.3 | 3.1 |
| 30" - 34" | 47.4 | 42.0 | 5.3 |
| 35" - 39" | 59.8 | 49.2 | 10.6 |
| 40" - 44" | 68.4 | 57.2 | 11.2 |
| 45" - 49" | 82.7 | 65.8 | 16.9 |
| 50" - 54" | 94.7 | 74.9 | 19.8 |
| 55" - 59" | 104.6 | 84.2 | 20.4 |
| 60" - 64" | 120.2 | 93.4 | 26.9 |
| 65" or greater | 135.7 | 107.2 | 28.5 |

For High Resolution TVs with native vertical resolution of 2160 lines or greater, additional On Power Consumption allowances are provided for both ENERGY STAR and Most Efficient TVs resulting in the following On Power energy savings.

| High Resolution Television Energy Use and Savings by Screen Size | | | |
|---|---|---|---|
| Diagonal screen size | Conventional | Most Efficient | kWh Savings |
| 20" and under | 42.2 | 40.6 | 1.6 |
| 21" - 23" | 55.6 | 44.4 | 11.2 |
| 24" - 29" | 57.5 | 51.1 | 6.4 |
| 30" - 34" | 71.0 | 61.0 | 10.1 |
| 35" - 39" | 89.7 | 71.3 | 18.3 |
| 40" - 44" | 102.5 | 82.9 | 19.6 |
| 45" - 49" | 124.0 | 95.4 | 28.6 |
| 50" - 54" | 142.1 | 108.6 | 33.5 |
| 55" - 59" | 157.0 | 122.1 | 34.9 |
| 60" - 64" | 180.3 | 135.4 | 44.9 |
| 65" or greater | 203.5 | 155.4 | 48.1 |

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = (kW_{base} - kW_{eff}) \text{ x } CF$$

*Where:*

$kW_{base}$ = *Baseline unit wattage varies by diagonal screen size.*

$kW_{eff}$ = *Efficient unit wattage varies by diagonal screen size. See above.*

*CF = 21%*[461]

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[461] Estimate based on On-mode hours per day (5 hours/day) as a percentage of all hours.

Summer coincident kW savings are:

| Diagonal screen size | Conventional | Most Efficient | kW Savings |
|---|---|---|---|
| 20" and under | 0.003 | 0.003 | 0.000 |
| 21" - 23" | 0.004 | 0.003 | 0.001 |
| 24" - 29" | 0.004 | 0.004 | 0.000 |
| 30" - 34" | 0.005 | 0.005 | 0.001 |
| 35" - 39" | 0.007 | 0.006 | 0.001 |
| 40" - 44" | 0.008 | 0.007 | 0.001 |
| 45" - 49" | 0.009 | 0.008 | 0.002 |
| 50" - 54" | 0.011 | 0.009 | 0.002 |
| 55" - 59" | 0.012 | 0.010 | 0.002 |
| 60" - 64" | 0.014 | 0.011 | 0.003 |
| 65" or greater | 0.015 | 0.012 | 0.003 |

For High Resolution TVs, the summer coincident demand savings are:

| Diagonal screen size | Conventional | Most Efficient | kW Savings |
|---|---|---|---|
| 20" and under | 0.005 | 0.005 | 0.000 |
| 21" - 23" | 0.006 | 0.005 | 0.001 |
| 24" - 29" | 0.007 | 0.006 | 0.001 |
| 30" - 34" | 0.008 | 0.007 | 0.001 |
| 35" - 39" | 0.010 | 0.008 | 0.002 |
| 40" - 44" | 0.012 | 0.009 | 0.002 |
| 45" - 49" | 0.014 | 0.011 | 0.003 |
| 50" - 54" | 0.016 | 0.012 | 0.004 |
| 55" - 59" | 0.018 | 0.014 | 0.004 |
| 60" - 64" | 0.021 | 0.015 | 0.005 |
| 65" or greater | 0.023 | 0.018 | 0.005 |

**Annual Fossil Fuel Savings Algorithm**

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The expected measure life is assumed to be 6 years.[462]

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[462] ENERGY STAR Consumer Electronics Calculator.

# COMMERCIAL & INDUSTRIAL MARKET SECTOR

*Lighting End Use*

## When replacing T12 fixtures in Maryland

In the absence of changes to programs to further constrain use of T12 baselines with burned out lamps, all T12 baseline fixtures should have their assumed wattage reduced by 21% for general prescriptive programs and 15% for small business programs, consistent with the assumed fraction of those lamps that are burned out at the time of early replacement.

# LED Exit Sign

## Unique Measure Code(s): CI_LT_EREP_LEDEXI_0518
## Effective Date: May 2018
## End Date: TBD

### Measure Description

This measure relates to the installation of an exit sign illuminated with light emitting diodes (LED). This measure should be limited to early replacement applications.

Note: While this measure is characterized as an early replacement, a dual baseline is not used as it is assumed that the existing fixture would have been maintained with new baseline lamps (and ballasts, if required) for the duration of the measure life.

### Definition of Baseline Condition

The baseline condition is an existing exit sign with a non-LED light-source.

### Definition of Efficient Condition

The efficient condition is a new exit sign illuminated with light emitting diodes (LED).

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE = Actual Connected load of existing exit sign. If connected load of existing exit sign is unknown, assume 16 W.*[463]

*WattsEE = Actual Connected load of LED exit sign*

*HOURS = Average hours of use per year*

*= 8,760* [464]

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

*= 1.00* [465]

*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

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[463] 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.

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

[465] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*
= *1.0* [466]

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta kWh / WHFe) * 0.00073.$$

*Where:*

*0.7* = *Aspect ratio* [467]
*0.003413* = *Constant to convert kWh to MMBTU*
*0.23* = *Fraction of lighting heat that contributes to space heating* [468]
*0.75* = *Assumed heating system efficiency* [469]

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 5 years.[470]

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

[467] 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.

[468] 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).

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

[470] To be ENERGY STAR labeled, an LED exit sign must be guaranteed to last at least 5 years, however, many manufacturers state that their lamps will maintain National Fire Protection Association compliant levels of luminance for 10 to 25 years.

# Solid State Lighting (LED) Recessed Downlight Luminaire

**Unique Measure Code: CI_LT_TOS_SSLDWN_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure describes savings from the purchase and installation of a Solid State Lighting (LED) Recessed Downlight luminaire in place of an incandescent downlight lamp (i.e. time of sale, including Midstream programs). The SSL downlight should meet the ENERGY STAR Luminaires Version 2.0 specification[471]. The characterization of this measure should not be applied to other types of LEDs.

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

### Definition of Baseline Condition

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

### Definition of Efficient Condition

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

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBase = Connected load of baseline lamp*
*= Find the equivalent baseline wattage based on the LED initial lumen output from the table below[472]; if unknown assume 65W[473] pre-2020 or 23W after January 1st, 2020.*

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

[472] Based on ENERGY STAR equivalence table; http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumenshttps://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_brightnes

[473] Energy Efficient wattage based on 12 Watt LR6 Downlight from LLF Inc. Adjusted by ratio of lm/w in ENERGY STAR V2.1 compared to ENERGY STAR V1.2 specification.

| Lower Lumen Range | Upper Lumen Range | 2018-2019 WattsBase | 2020+ WattsBase[474] |
|---|---|---|---|
| 400 | 449 | 40 | * |
| 450 | 499 | 45 | * |
| 500 | 649 | 50 | * |
| 650 | 1419 | 65 | * |
| 1420 | 1789 | 75 | * |
| 1790 | 2049 | 90 | * |
| 2050 | 2579 | 100 | * |
| 2580 | 3299 | 120 | * |
| 3300 | 4270 | 150 | 150 |
| *For lamps and fixtures < 3300 lumens, the baseline after 2020 should be calculated as WattsBase = (LumensEE / 45)[475] | | | |

*LumensEE* = *Lumen output of efficient lamp.*
= *Actual. If unknown assume 650 lumens*[476].

*WattsEE* = *Connected load of efficient lamp*
= *Actual. If unknown assume 9.2W* [477]

*ISR* = *In Service Rate or percentage of units rebated that get installed.*
= *1.0*[478]

*HOURS* = *Deemed average hours of use per year*
= *See tables "C&I Downstream and Midstream Lighting Parameters" in Appendix D.*

*WHFe* = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

### Summer Coincident Peak kW Savings Algorithm

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

*Where:*

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[474] Different jurisdictions may have different implementation start dates for the 2020 baseline shift.

[475] In 2020 the EISA backstop takes effect and the minimum efficacy for all lamps and fixtures becomes 45 lumens/W. https://www.energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf

[476] Calculated using the minimum lumen output for a BR lamp of 650 lumens.

[477] Calculated using the minimum lumen output for a BR lamp of 650 lumens and the 60 lumens per watt specified by ENERGY STAR v2. 1 for luminaires with a CRI < 90.

[478] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*
= *See tables "C&I Downstream and Upstream Lighting Parameters" in Appendix D.*

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

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

$$= (-\Delta kWh / WFHe) * 0.00073$$

*Where:*

*0.7* = *Aspect ratio* [479]

*0.003413* = *Constant to convert kWh to MMBTU*

*0.23* = *Fraction of lighting heat that contributes to space heating* [480]

*0.75* = *Assumed heating system efficiency* [481]

**Annual Water Savings Algorithm**

n/a

**Measure Life**

Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. However, measure life is not to exceed 15 years[482].The fixture life should be assumed to be 25,000 hours for separable luminaires and 50,000 hours for inseparable luminaires[483].

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[479] 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.

[480] 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).

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

[482] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[483] The ENERGY STAR specification for solid state recessed downlights requires luminaires using LED lamps to maintain >=70% initial light output for 25,000 hours in an indoor application for separable luminaires and 50,000 for inseparable luminaires.

# Delamping

**Unique Measure Code(s): CI_LT_ERT_DELAMP_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the permanent removal of a lamp and the associated electrical sockets (or “tombstones”) from a fixture.

### Definition of Baseline Condition

The baseline conditions will vary dependent upon the characteristics of the existing fixture.

### Definition of Efficient Condition

The efficient condition will vary depending on the existing fixture and the number of lamps removed.

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE = Actual Connected load of baseline fixture*
*WattsEE = Actual Connected load of delamped fixture*
*HOURS = Deemed average hours of use per year*
*= See tables “C&I Downstream Lighting Parameters” in Appendix D.*
*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

### Summer Coincident Peak kW Savings Algorithm

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

*Where:*

*WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*
*CF = Summer Peak Coincidence Factor for measure*
*= See table “C&I Downstream Lighting Parameters” in Appendix D.*

### Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$

$= (-\Delta kWh / WHFe) * 0.00073.$

*Where:*

*0.7 = Aspect ratio* [484]

*0.003413 = Constant to convert kWh to MMBTU*

*0.23 = Fraction of lighting heat that contributes to space heating* [485]

*0.75 = Assumed heating system efficiency* [486]

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 15 years.[487]

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[484] 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.

[485] 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).

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

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

# Occupancy Sensor – Wall-, Fixture-, or Remote-Mounted

**Unique Measure Code(s): CI_LT_RF_OSWALL_0518, CI_LT_RF_OSFIX/REM_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure defines the savings associated with installing a wall-, fixture, or remote-mounted occupancy sensor that switches lights off after a brief delay when it does not detect occupancy.

### Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

### Definition of Efficient Condition

The efficient condition is lighting that is controlled with an occupancy sensor.

### Annual Energy Savings Algorithm

$$\Delta kWh = kWconnected * HOURS * SVGe * ISR * WHFe$$

*Where:*

*kWconnected = Assumed kW lighting load connected to control.*
*HOURS = Deemed average hours of use per year.*
*= See tables "C&I Downstream Lighting Parameters" in Appendix D.*
*SVGe = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
*= 0.28* [488]
*ISR = In Service Rate or percentage of units rebated that get installed*
*= 1.00* [489]
*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

### Summer Coincident Peak kW Savings Algorithm

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

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[488] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

[489] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

*Where:*

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

= *0.14* [490]

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*

= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*

= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

Illustrative examples – do not use as default assumption.

For example, a 400W connected load being controlled in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 * 0.14 * 1.00 * 1.32 * 0.69$$

$$= 0.051 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$$

$$= (-\Delta kWh / WHFe) * 0.00073.$$

*Where:*

*0.7* = *Aspect ratio* [491]

*0.003413* = *Constant to convert kWh to MMBTU*

*0.23* = *Fraction of lighting heat that contributes to space heating* [492]

*0.75* = *Assumed heating system efficiency* [493]

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[490] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

[491] 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.

[492] 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).

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

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 10 years.[494]

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

# Daylight Dimming Control

**Unique Measure Code(s): CI_LT_TOS_DDIM_0518, CI_LT_RF_DDIM_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure defines the savings associated with installing a daylighting dimming control system to reduce electric lighting levels during periods of high natural light. Systems typical include daylight sensors, control electronics, and, if necessary, dimmable ballasts.

### Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

### Definition of Efficient Condition

The efficient condition is lighting that is controlled with a daylight dimming system capable of continuous dimming to reduce electric lighting to the lowest possible levels during periods of adequate natural light.

### Annual Energy Savings Algorithm

$$\Delta kWh = kWconnected \times HOURS \times SVG \times ISR \times WHFe$$

*Where:*

*kWconnected = Assumed kW lighting load connected to control.*

*HOURS = Deemed average hours of use per year*
*= See tables "C&I Downstream Lighting Parameters" in Appendix D.*

*SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using default below.*
*= 0.28* [495]

*ISR = In Service Rate or percentage of units rebated that get installed*
*= 1.00* [496]

*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

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[495] Williams, A., B. Atkinson, K. Garesi, E. Page, and F. Rubinstein. 2012. "Lighting Controls in Commercial Buildings." The Journal of the Illuminating Engineering Society of North America 8 (3): 161-180.

[496] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

**Summer Coincident Peak kW Savings Algorithm**[497]

$$\Delta kW = kWconnected \times SVG \times ISR \times WHFd \times CF$$

*Where:*

*WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF = Summer Peak Coincidence Factor for measure*
*= See table "C&I Downstream Lighting Parameters" in Appendix D.*

Illustrative examples – do not use as default assumption

For example, a 400W connected load being controlled in a conditoned office building with gas heat in BGE service territory in 2014 and estimating PJM summer peak coincidence:

$$\Delta kW = 0.4 * 0.28 * 1.00 * 1.32 * 0.69$$

$$= 0.10 \text{ kW}$$

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta kWh / WHFe) * 0.00073.$$

*Where:*

*0.7 = Aspect ratio*[498]
*0.003413 = Constant to convert kWh to MMBTU*
*0.23 = Fraction of lighting heat that contributes to space heating*[499]
*0.75 = Assumed heating system efficiency*[500]

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[497] As a conservative assumption, the peak demand savings algorithm assumes the same annual savings factor (SVG) as the energy savings equation. It is probable that higher than average availability of daylight coincides with summer peak periods. This factor is a candidate for future study as increased accuracy will likely lead to increased peak demand savings estimates.

[498] 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.

[499] 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).

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

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 10 years.[501]

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

# Advanced Lighting Design – Commercial

**0420**

**Effective Date: April 2020**

**End Date: TBD**

### Measure Description

Advanced lighting design refers to the implementation of various lighting design principles aimed at creating a quality and appropriate lighting experience while reducing unnecessary light usage. This is often done by a professional in a new construction situation. Advanced lighting design uses techniques like maximizing task lighting and efficient fixtures to create a system of optimal energy efficiency and functionality to ultimately reduce the wattage required per square foot while maintaining acceptable lumen levels.

This measure characterization is intended for use in new construction or in existing buildings where significant lighting renovations are taking place and energy code requirements must be met.

### Definition of Baseline Condition

The baseline condition assumes compliance with lighting power density requirements as mandated by jurisdiction: Maryland Building Performance Standards (2015 International Energy Conservation Code); Title 16, Chapter 76 of the Delaware Code (2012 International Energy Conservation Code); and District of Columbia Construction Codes Supplement of 2013 (2012 International Energy Conservation Code). Because lighting power density requirements differ by jurisdiction, this measure entry presents two different baseline conditions to be used in each of the three relevant jurisdictions. For completeness, the lighting power density requirements for both the Building Area Method and the Space-by-Space Method are presented.[502]

### Definition of Efficient Condition

The efficient condition assumes lighting systems that achieve lighting power densities below the maximum lighting power densities required by the relevant jurisdictional energy codes as described above. Actual lighting power densities should be determined on a site-specific basis.

### Annual Energy Savings Algorithm[503]

$$\Delta kWh = ((LPDBASE - LPDEE) / 1000) * AREA * HOURS * WHFe$$

---

[502] Energy code lighting power density requirements can generally be satisfied by using one of two methods. The Building Area Method simply applies a blanket LPD requirement to the entire building based on the building type. Broadly speaking, as long as the total connected lighting wattage divided by the total floor space does not exceed the LPD requirement, the code is satisfied. The second method, the Space-by-Space Method, provides LPD requirements by space type based on the function of the particular space (e.g., “Hospital – Operating Room”, “Library – Reading Room”). LPD requirements must be satisfied for each individual space in the building. This method usually allows a higher total connected wattage as compared to the Building Area Method.

[503] If the Space-by-Space Method is used, the total energy savings will be the sum of the energy savings for each individual space type.

*Where:*

*LPDBASE = Baseline lighting power density for building or space type (W/ft$^2$). See tables below for values by jurisdiction and method.*[504]

*LPDEE = Efficient lighting power density (W/ft$^2$)*

*= Actual calculated*

*AREA = Building or space area (ft$^2$)*

*HOURS = Deemed average hours of use per year*

*= See tables "C&I Downstream Lighting Parameters" in Appendix D.*

*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

**Building Area Method Baseline LPD Requirements by Jurisdiction**[505]

| | **Lighting Power Density (W/ft$^2$)** | |
|---|---|---|
| **Building Area Type** | **Washington, D.C. and Delaware** | **Maryland** |
| Automotive Facility | 0.90 | 0.80 |
| Convention Center | 1.20 | 1.01 |
| Court House | 1.20 | 1.01 |
| Dining: Bar Lounge/Leisure | 1.30 | 1.01 |
| Dining: Cafeteria/Fast Food | 1.40 | 0.90 |
| Dining: Family | 1.60 | 0.95 |
| Dormitory | 1.00 | 0.57 |
| Exercise Center | 1.00 | 0.84 |
| Fire Station | 0.80 | 0.67 |
| Gymnasium | 1.10 | 0.94 |
| Healthcare-Clinic | 1.00 | 0.90 |
| Hospital | 1.20 | 1.05 |
| Hotel | 1.00 | 0.87 |

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[504] Codes changes affecting lighting power density requirements are likely to occur for at least some jurisdictions between June 2017 and June 2018; however, revised requirements are not yet known. Any code updated will be reflected in the June 2018-May 2019 TRM (V8).

[505] IECC 2015, Table C405.4.2 (1); IECC 2012, Table C405.5.2 (1). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2010, Table 9.5.1. As the IECC 2012 requirements are less stringent they are presented here.

| | Lighting Power Density (W/ft$^2$) | |
|---|---|---|
| **Building Area Type** | **Washington, D.C. and Delaware** | **Maryland** |
| Library | 1.30 | 1.19 |
| Manufacturing Facility | 1.30 | 1.17 |
| Motel | 1.00 | 0.87 |
| Motion Picture Theatre | 1.20 | 0.76 |
| Multi-Family | 0.70 | 0.51 |
| Museum | 1.10 | 1.02 |
| Office | 0.90 | 0.82 |
| Parking Garage | 0.30 | 0.21 |
| Penitentiary | 1.00 | 0.81 |
| Performing Arts Theatre | 1.60 | 1.39 |
| Police Station | 1.00 | 0.87 |
| Post Office | 1.10 | 0.87 |
| Religious Building | 1.30 | 1.00 |
| Retail | 1.40 | 1.26 |
| School/University | 1.20 | 0.87 |
| Sports Arena | 1.10 | 0.91 |
| Town Hall | 1.10 | 0.89 |
| Transportation | 1.00 | 0.70 |
| Warehouse | 0.60 | 0.66 |
| Workshop | 1.40 | 1.19 |

**Space-by-Space Method Baseline LPD Requirements for Washington, D.C. and Delaware**[506]

| Common Space-By-Space Types | Lighting Power Density (W/ft$^2$) |
|---|---|
| Atrium - First 40 feet in height | 0.03 per ft. ht. |
| Atrium - Above 40 feet in height | 0.02 per ft. ht. |

---

[506] IECC 2012, Table C405.5.2(2). Note that the Delaware energy code may also be satisfied by meeting the requirements of ASHRAE 90.1-2010, Table 9.5.1. As the IECC 2012 requirements are less stringent they are presented here.

| | |
|---|---|
| Audience/seating area - Permanent | |
| For auditorium | 0.9 |
| For performing arts theater | 2.6 |
| For motion picture theater | 1.2 |
| Classroom/lecture/training | 1.3 |
| Conference/meeting/multipurpose | 1.2 |
| Corridor/transition | 0.7 |
| Dining Area | |
| Bar/lounge/leisure dining | 1.4 |
| Family dining area | 1.4 |
| Dressing/fitting room performing arts theater | 1.1 |
| Electrical/mechanical | 1.1 |
| Food preparation | 1.2 |
| Laboratory for classrooms | 1.3 |
| Laboratory for medical/industrial/research | 1.8 |
| Lobby | 1.1 |
| Lobby for performing arts theater | 3.3 |
| Lobby for motion picture theater | 1.0 |
| Locker room | 0.8 |
| Lounge recreation | 0.8 |
| Office – enclosed | 1.1 |
| Office - open plan | 1.0 |
| Restroom | 1.0 |
| Sales area | 1.6 |
| Stairway | 0.7 |
| Storage | 0.8 |
| Workshop | 1.6 |
| Courthouse/police station/penitentiary | |
| Courtroom | 1.9 |
| Confinement cells | 1.1 |
| Judge chambers | 1.3 |

| | |
|---|---|
| Penitentiary audience seating | 0.5 |
| Penitentiary classroom | 1.3 |
| Penitentiary dining | 1.1 |

| **Building Specific Space-By-Space Types** | **Lighting Power Density (W/ft$^2$)** |
|---|---|
| Automobile – service/repair | 0.7 |
| Bank/office - banking activity area | 1.5 |
| Dormitory living quarters | 1.1 |
| Gymnasium/fitness center | |
| Fitness area | 0.9 |
| Gymnasium audience/seating | 0.4 |
| Playing area | 1.4 |
| Healthcare clinic/hospital | |
| Corridor/transition | 1.0 |
| Exam/treatment | 1.7 |
| Emergency | 2.7 |
| Public and staff lounge | 0.8 |
| Medical supplies | 1.4 |
| Nursery | 0.9 |
| Nurse station | 1.0 |
| Physical therapy | 0.9 |
| Patient Room | 0.7 |
| Pharmacy | 1.2 |
| Radiology/imaging | 1.3 |
| Operating room | 2.2 |
| Recovery | 1.2 |
| Lounge/recreation | 0.8 |
| Laundry - washing | 0.6 |
| Hotel | |
| Dining area | 1.3 |
| Guest rooms | 1.1 |
| Hotel lobby | 2.1 |

| | |
|---|---|
| Highway lodging dining | 1.2 |
| Highway lodging guest rooms | 1.1 |
| Library | |
| Stacks | 1.7 |
| Card file and cataloging | 1.1 |
| Reading area | 1.2 |
| Manufacturing | |
| Corridor/transition | 0.4 |
| Detailed manufacturing | 1.3 |
| Equipment room | 1.0 |
| Extra high bay (>50-foot floor-ceiling height) | 1.1 |
| High bay (25-50-foot floor-ceiling height) | 1.2 |
| Low bay (<25-foot floor-ceiling height) | 1.2 |
| Museum | |
| General exhibition | 1.0 |
| Restoration | 1.7 |
| Parking garage – garage areas | 0.2 |
| Convention center | |
| Exhibit space | 1.5 |
| Audience/seating area | 0.9 |
| Fire stations | |
| Engine room | 0.8 |
| Sleeping quarters | 0.3 |
| Post office – sorting area | 0.9 |
| Religious building | |
| Fellowship hall | 0.6 |
| Audience seating | 2.4 |
| Worship pulpit/choir | 2.4 |
| Retail | |
| Dressing/fitting area | 0.9 |
| Mall concourse | 1.6 |

| | |
|---|---|
| Sales area | 1.6 |
| Sports arena | |
| Audience seating | 0.4 |
| Court sports area - Class 4 | 0.7 |
| Court sports area - Class 3 | 1.2 |
| Court sports area - Class 2 | 1.9 |
| Court sports area - Class 1 | 3.0 |
| Ring sports arena | 2.7 |
| Transportation | |
| Airport/train/bus baggage area | 1.0 |
| Airport concourse | 0.6 |
| Terminal - ticket counter | 1.5 |
| Warehouse | |
| Fine material storage | 1.4 |
| Medium/bulky material | 0.6 |

**Space-by-Space Method Baseline LPD Requirements for Maryland**[507]

| Common Space-By-Space Types | Lighting Power Density (W/ft$^2$) |
|---|---|
| Atrium | |
| Less than 40 feet in height | 0.03 per foot in total height |
| Greater than 40 feet in height | 0.40 + 0.02 per foot in total height |
| Audience seating area | |
| In an auditorium | 0.63 |
| In a convention center | 0.82 |
| In a gymnasium | 0.65 |
| In a motion picture theater | 1.14 |
| In a penitentiary | 0.28 |
| In a performing arts theater | 2.43 |
| In a religious building | 1.53 |
| In a sports arena | 0.43 |

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[507] IECC 2015, Table C405.4.2 (2).

| | |
|---|---|
| Otherwise | 0.43 |
| Banking activity area | 1.01 |
| Breakroom (See Lounge/Breakroom) | |
| Classroom/lecture hall/training room | |
| In a penitentiary | 1.34 |
| Otherwise | 1.24 |
| Conference/meeting/multipurpose room | 1.23 |
| Copy/print room | 0.72 |
| Corridor | |
| In a facility for the visually impaired (and not used primarily by staff) | 0.92 |
| In a hospital | 0.79 |
| In a manufacturing facility | 0.41 |
| Otherwise | 0.66 |
| Courtroom | 1.72 |
| Computer room | 1.71 |
| Dining area | |
| In a penitentiary | 0.96 |
| In a facility for the visually impaired (and not used primarily by staff) | 1.9 |
| In bar/lounge or leisure dining | 1.07 |
| In cafeteria or fast food dining | 0.65 |
| In family dining | 0.89 |
| Otherwise | 0.65 |
| Electrical/mechanical room | 0.95 |
| Emergency vehicle garage | 0.56 |
| Food preparation area | 1.21 |
| Guest room | 0.47 |
| Laboratory | |
| In or as a classroom | 1.43 |
| Otherwise | 1.81 |
| Laundry/washing area | 0.6 |
| Loading dock, interior | 0.47 |

| | |
|---|---|
| Lobby | |
| In a facility for the visually impaired (and not used primarily by the staff) | 1.8 |
| For an elevator | 0.64 |
| In a hotel | 1.06 |
| In a motion picture theater | 0.59 |
| In a performing arts theater | 2.0 |
| Otherwise | 0.9 |
| Locker room | 0.75 |
| Lounge/breakroom | |
| In a healthcare facility | 0.92 |
| Otherwise | 0.73 |
| Office | |
| Enclosed | 1.11 |
| Open plan | 0.98 |
| Parking area, interior | 0.19 |
| Pharmacy area | 1.68 |
| Restroom | |
| In a facility for the visually impaired (and not used primarily by the staff) | 1.21 |
| Otherwise | 0.98 |
| Sales area | 1.59 |
| Seating area, general | 0.54 |
| Stairway (See space containing stairway) | |
| Stairwell | 0.69 |
| Storage room | 0.63 |
| Vehicular maintenance area | 0.67 |
| Workshop | 1.59 |
| **Building Type Specific Space Types** | **Lighting Power Density (W/ft$^2$)** |
| Facility for the visually impaired | |
| In a chapel (and not used primarily by the staff) | 2.21 |

| | |
|---|---|
| In a recreation room (and not used primarily by the staff) | 2.41 |
| Automotive (See Vehicular Maintenance Area above) | |
| Convention Center – exhibit space | 1.45 |
| Dormitory – living quarters | 0.38 |
| Fire Station – sleeping quarters | 0.22 |
| Gymnasium/fitness center | |
| In an exercise area | 0.72 |
| In a playing area | 1.2 |
| Healthcare facility | |
| In an exam/treatment room | 1.66 |
| In an imaging room | 1.51 |
| In a medical supply room | 0.74 |
| In a nursery | 0.88 |
| In a nurse’s station | 0.71 |
| In an operating room | 2.48 |
| In a patient room | 0.62 |
| In a physical therapy room | 0.91 |
| In a recovery room | 1.15 |
| Library | |
| In a reading area | 1.06 |
| In the stacks | 1.71 |
| Manufacturing facility | |
| In a detailed manufacturing facility | 1.29 |
| In an equipment room | 0.74 |
| In an extra high bay area (greater than 50’ floor-to-ceiling height) | 1.05 |
| In a high bay area (25’-50’ floor-to-ceiling height) | 1.23 |
| In a low bay area (less than 25’ floor-to-ceiling height) | 1.19 |
| Museum | |
| In a general exhibition area | 1.05 |
| In a restoration room | 1.02 |

| | |
|---|---|
| Performing arts theater – dressing room | 0.61 |
| Post Office – Sorting Area | 0.94 |
| Religious buildings | |
| In a fellowship hall | 0.64 |
| In a worship/pulpit/choir area | 1.53 |
| Retail facilities | |
| In a dressing/fitting room | 0.71 |
| In a mall concourse | 1.1 |
| Sports arena – playing area | |
| For a Class I facility | 3.68 |
| For a Class II facility | 2.4 |
| For a Class III facility | 1.8 |
| For a Class IV facility | 1.2 |
| Transportation facility | |
| In a baggage/carousel area | 0.53 |
| In an airport concourse | 0.36 |
| At a terminal ticket counter | 0.8 |
| Warehouse – storage area | |
| For medium to bulky, palletized items | 0.58 |
| For smaller, hand-carried items | 0.95 |

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 $ft^2$ conditoned office building with gas heat in in DE using the Building Area Method with an LPDEE of 0.75:

$$\Delta kWh = ((0.9 - 0.75) / 1000) * 15{,}000 * 2{,}969 * 1.10$$

$$= 7{,}348 \text{ kWh}$$

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = ((LPDBASE – LPDEE) / 1000) * AREA * WHFd * CF$$

*Where:*

*WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*

*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF = Summer Peak Coincidence Factor for measure*
*= See table “C&I Downstream Lighting Parameters” in Appendix D.*

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft$^2$ conditoned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75 and estimating PJM summer peak coincidence:

$$\Delta kWh = ((0.9 - 0.75) / 1000) * 15{,}000 * 1.32 * 0.69$$

$$= 2.05\ kW$$

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

*Where:*

*0.7 = Aspect ratio* [508]
*0.003413 = Constant to convert kWh to MMBTU*
*0.23 = Fraction of lighting heat that contributes to space heating* [509]
*0.75 = Assumed heating system efficiency* [510]

Illustrative examples – do not use as default assumption

For example, assuming a 15,000 ft$^2$ conditoned office building with gas heat in DE using the Building Area Method with an LPDEE of 0.75:

$$\Delta kWh = (-7{,}348 / 1.10) * 0.00073$$

$$= -4.88\ MMBTU$$

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[508] 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.

[509] 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).

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

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 15 years.[511]

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[511] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007, http://www.ctsavesenergy.org/files/Measure%20Life%20Report%202007.pdf. Assumes Advanced Lighting Design lifetime will be consistent with that of the "Fluorescent Fixture" measure from the reference document. This measure life assumes that the most common implementation of this measure will be for new construction or major renovation scenarios where new fixtures are installed. In such cases, adopting the fixture lifetime for the LPD reduction measure seems most appropriate.

# LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Luminaires and Retrofit Kits

**Unique Measure Code(s): CI_LT_TOS_LEDODPO_0420, CI_LT_RF_LEDODPO_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of an LED outdoor pole/arm- or wall-mounted luminaire or retrofit kit for parking lot, street, or general area illumination in place of a high-intensity discharge light source. Eligible applications include time of sale or new construction and retrofit applications.

### Definition of Baseline Condition

The baseline condition is defined as an outdoor pole/arm- or wall-mounted luminaire with a high intensity discharge light-source. Typical baseline technologies include metal halide (MH) and high pressure sodium (HPS) lamps.

### Definition of Efficient Condition

The efficient condition is defined as an LED outdoor pole/arm- or wall-mounted luminaire or retrofit kit.

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE = Actual Connected load of baseline fixture*
*= If the actual baseline fixture wattage is unknown, use the default values presented in the "Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage" table below.*

*WattsEE = Actual Connected load of the LED fixture*
*= If the actual LED fixture wattage is unknown, use the default values presented in the "Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage" table below based on the appropriate baseline description.*

### Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Lighting Baseline and Efficient Wattage[512]

| Measure Category | Baseline Description | WattsBASE | Efficient Description | WattsEE |
|---|---|---|---|---|
| LED Outdoor Area Fixture replacing up to 175W HID | 175W or less base HID | 171 | DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires | 99 |
| LED Outdoor Area Fixture replacing 176-250W HID | 176W up to 250W base HID | 288 | DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires | 172 |
| LED Outdoor Area Fixture replacing 251-400W HID | 251W up to 400W base HID | 452 | DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires | 293 |
| LED Outdoor Area Fixture replacing 401-1000W HID | 401W up to 1000W base HID | 1075 | DLC Qualified LED Outdoor Pole/Arm- or Wall-Mounted Area and Roadway Luminaires | 663 |

*HOURS = Average hours of use per year*

*= If annual operating hours are unknown, assume 3,604* [513]*. Otherwise, use site specific annual operating hours information.*[514]

Illustrative examples – do not use as default assumption

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[512] Baseline and efficient fixtures have been grouped into wattage categories based on typical applications. The typical baseline equipment in each group was weighted based on personal communication with Kyle Hemmi, CLEAResult on Sept. 18. 2012. Weighting reflects implementation program data from Texas, Nevada, Rocky Mountain, and Southwest Regions. When adequate program data is collected from the implementation of this measure in the Mid-Atlantic region, these weightings should be updated accordingly. Baseline fixture wattage assumptions developed from multiple TRMs including: Arkansas TRM Version 2.0, Volume 2: Deemed Savings, Frontier Associates, LLC, 2012; Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2012 Program Year – Plan Version, Massachusetts Electric and Gas Energy
Efficiency Program Administrators, 2011, and 2012 Statewide Customized Offering Procedures Manual for Business - Appendix B Table of Standard Fixture Wattages and Sample Lighting Table, Southern California Edison et al., 2012. As the total wattage assumptions for like fixtures typically do not vary by more than a few watts between sources, the values from the Arkansas document have been adopted here. Efficient fixture wattage estimated assuming mean delivered lumen equivalence between the baseline and efficient case. Baseline initial lamp lumen output was reduced by estimates of lamp lumen depreciation and optical efficiency. Efficient wattage and lumen information was collected from appropriate product categories listed in the DesignLights Consortium Qualified Products List – Updated 11/21/2012. Analysis presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" supporting workbook.

[513] Navigant Commercial and Industrial Long Term Metering Study.

[514] Site-specific annual operating hours should be collected following best-practice data collection techniques as appropriate. Any use of site-specific annual operating hours information will be subject to regulatory approval and potential measurement and verification adjustment. Maintain a consistent approach with the intent of reporting accurate savings; do not use site-specific hours in some cases and Appendix D hours in others to boost savings.

For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\Delta kWh = ((288 – 172) / 1000) * 3{,}604$$

$$= 418\ kWh$$

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*CF = Summer Peak Coincidence Factor for measure*
*= 0.11* [515]

Illustrative examples – do not use as default assumption

For example, a 250W metal halide fixture is replaced with an LED fixture:

$$\Delta kW = ((288 - 172) / 1000) * 0.11$$

$$= 0.013\ kW$$

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[516] hours. However, measure life is not to exceed 15 years[517].

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[515] Navigant Commercial and Industrial Long Term Metering Study.

[516] The minimum rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/14/2018 < https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/> is 50,000 hours for exterior fixtures. Assuming average annual operating hours of 3,338 (Efficiency Vermont TRM User Manual No. 2014-85b; based on 5 years of metering on 235 outdoor circuits in New Jersey), the estimated measure life is 15 years.

[517] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# LED High-Bay Luminaires and Retrofit Kits

**Unique Measure Code(s): CI_LT_TOS_LEDHB_0420, CI_LT_RF_LEDHB_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of an LED high-bay luminaire or retrofit kit for general area illumination in place of a high-intensity discharge or fluorescent light source. Eligible applications include time of sale or new construction luminaires and retrofit kits installed at a minimum height of 20 feet. Because of the improved optical control afforded by LED luminaires and retrofit kits, LED lighting systems can typically reduce total lumen output while maintaining required illuminance on work surfaces. Therefore, illuminance calculations should be performed in the process of selecting LED luminaires.

### Definition of Baseline Condition

The baseline condition is defined as a high-bay luminaire with a high intensity discharge or fluorescent light-source. Typical baseline technologies include pulse-start metal halide (PSMH) and fluorescent T5 high-output fixtures. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. light source technology, number of lamps). For retrofit applications, the baseline is the existing fixture.

### Definition of Efficient Condition

The efficient condition is defined as an LED high-bay luminaire. Eligible fixtures must be listed on the DesignLights Consortium Qualified Products List[518].

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE = Actual Connected load of baseline fixture*
*WattsEE = Actual Connected load of the LED fixture*
*HOURS = deemed average hours of use per year*
*= See tables "C&I Downstream Lighting Parameters" in Appendix D.*
*ISR = In Service Rate or percentage of units rebated that get installed*
*= 1.00* [519]
*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

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[518] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[519] Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the "Equipment" category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

### Summary Coincident Peak kW Savings Algorithm

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

### Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 1.0 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta kWh / WHFe) * 0.00073.$$

*Where:*

*1.0* = *Aspect ratio* [520]
*0.003413* = *Constant to convert kWh to MMBTU*
*0.23* = *Fraction of lighting heat that contributes to space heating* [521]
*0.75* = *Assumed heating system efficiency* [522]

### Annual Water Savings Algorithm

n/a

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[520] As this measure will likely be installed in building types without defined perimeter zones (e.g., warehouses, gymnasiums, and manufacturing) no adjustment for perimeter zone aspect ratio is necessary.

[521] 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).

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

**Measure Life**

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[523] hours. However, measure life is not to exceed 15 years[524].

---

[523] Minimum DesignLights Consortium requirement is 50,000 hours for high bay fixtures. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[524] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# LED High-Intensity Discharge Screw Base

**Unique Measure Code(s): CI_LT_TOS_LEDHID_0518, CI_LT_RF_LEDHID_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a screw based LED lamp in place of a high-intensity discharge lamp. Eligible applications include time of sale or retrofit lamps.

### Definition of Baseline Condition

The baseline condition is defined as a mogul (E39 or EX39) screw based high-intensity discharge bulb, using metal halide technology. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the lamp installed (e.g., wattage). For retrofit applications, the baseline is the existing bulb.

### Definition of Efficient Condition

The efficient condition is defined as a mogul (E39 or EX39) screw-based LED lamp. Eligible bulbs must be listed on the DesignLights Consortium Qualified Products List.[525]

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE = Rated wattage of in-situ lamp. If the actual baseline lamp wattage is unknown, use the default values presented in the "LED Screw-Base Retrofit HID Lamps Baseline and Efficient Wattage" table below based on the appropriate baseline description.*

***LED Screw-Base Retrofit HID Lamps Baseline and Efficient Wattage*** [526]

| Measure Category | Baseline Description | WattsBASE | Efficient Description | WattsEE |
|---|---|---|---|---|
| LED Retrofit Lamp replacing up to 175W HID | 175W or less base HID | 175 | DLC Qualified LED Screw-In with Mogul Base (E39 or EX39) | 45 |
| LED Retrofit Lamp replacing 176-250W HID | 176W up to 250W base HID | 250 | DLC Qualified LED Screw-In with Mogul Base (E39 or EX39) | 75 |

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[525] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[526] Baseline and efficient lamps have been grouped into wattage categories based on typical applications. Efficient wattage and lumen information was collected from appropriate product categories listed in the DesignLights Consortium Qualified Products List – Updated 3/16/2018.

| Measure Category | Baseline Description | WattsBASE | Efficient Description | WattsEE |
|---|---|---|---|---|
| LED Retrofit Lamp replacing 251-400W HID | 251W up to 400W base HID | 400 | DLC Qualified LED Screw-In with Mogul Base (E39 or EX39) | 132 |

*WattsEE* = *Rated wattage of the LED replacement bulb*
*HOURS* = *Deemed average hours of use per year*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*
*ISR* = *In Service Rate or percentage of units rebated that get installed*
= *1.00* [527]
*WHFe* = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is outdoors or unconditioned, assume WHFe = WHFd = 1.0.*

## Summer Coincident Peak kW Savings Algorithm

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or if the space is outdoors or unconditioned, assume WHFe = WHFd = 1.0.*
*CF* = *Summer Peak Coincidence Factor for measure*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

## Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 1.0 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00105$$

*Where:*

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[527] Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the "Equipment" category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

*1.0* = *Aspect ratio* [528]
*0.003413* = *Constant to convert kWh to MMBTU*
*0.23* = *Fraction of lighting heat that contributes to space heating* [529]
*0.75* = *Assumed heating system efficiency* [530]

**Annual Water Savings Algorithm**

n/a

**Measure Life**

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[531] hours. However, measure life is not to exceed 15 years[532].

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[528] As this measure will likely be installed in building types without defined perimeter zones (e.g., warehouses, gymnasiums, and manufacturing) no adjustment for perimeter zone aspect ratio is necessary.

[529] 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).

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

[531] Minimum DesignLights Consortium requirement is 50,000 hours for applicable E39 replacement lamp products. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[532] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# LED 1x4, 2x2, and 2x4 Luminaires and Retrofit Kits

**Unique Measure Code(s): CI_LT_TOS_LED1x4_0420, CI_LT_TOS_LED2x2_0420, CI_LT_TOS_LED2x4_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of an LED 1x4, 2x2, or 2x4 luminaire or retrofit kit for general area illumination in place of a fluorescent light source. These luminaires and retrofit kits are typically recessed, suspended, or surface-mounted and intended to provide ambient lighting in settings such as office spaces, schools, retail stores, and other commercial environments. Eligible applications include time of sale or new construction and retrofits applications. Because of the improved optical control afforded by LED luminaires and retrofit kits, LED lighting systems can typically reduce total lumen output while maintaining required illuminance on work surfaces. Therefore, illuminance calculations should be performed in the process of selecting LED luminaires and retrofit kits.

### Definition of Baseline Condition

The baseline condition is defined as a 1x4, 2x2, or 2x4 fixture with a fluorescent light-source. Typical baseline technologies include fluorescent T8 fixtures. For time of sale applications, the baseline condition will vary depending upon the specific characteristics of the fixtures installed (e.g. number of lamps).

### Definition of Efficient Condition

The efficient condition is defined as an LED high-bay luminaire.

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE = Actual Connected load of baseline fixture*
*WattsEE = Actual Connected load of the LED fixture*
*HOURS = Average hours of use per year*
*= Deemed average hours if use. See tables “C&I Downstream Lighting Parameters” in Appendix D.*[533]
*ISR = In Service Rate or percentage of units rebated that get installed*
*= 1.00* [534]

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[533] The lighting hours of use tables in Appendix D are primarily based on fluorescent lamp operating hours. It is assumed that, for general ambient lighting applications, LED operating hours will be similar to fluorescent operating hour; however, LED operating hours are a potential candidate for future study.

[534] Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the “Equipment” category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

*WHFe* = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

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

*Where:*

*0.7* = *Aspect ratio* [535]

*0.003413* = *Constant to convert kWh to MMBTU*

*0.23* = *Fraction of lighting heat that contributes to space heating* [536]

*0.75* = *Assumed heating system efficiency* [537]

**Annual Water Savings Algorithm**

n/a

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[535] 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.

[536] 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).

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

**Measure Life**

The measure life is assumed to be 14 years.[538]

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[538] The median rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/3/2015 <https://www.designlights.org/resources/file/NEEPDLCQPL> is 50,000 hours for both luminaires and retrofit kits. Assuming average annual operating hours of 3,500 for a typical commercial lighting application, the estimated measure life is 14 years.

# LED Parking Garage/Canopy Luminaires and Retrofit Kits

**Unique Measure Code(s): CI_LT_TOS_LEDODPG_0518, CI_LT_RF_LEDODPG_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the installation of an LED parking garage or fuel pump canopy luminaire or retrofit kit in place of a high-intensity discharge light source. Eligible applications include time of sale or new construction and retrofit applications.

### Definition of Baseline Condition

The baseline condition is defined as a parking garage or canopy luminaire with a high intensity discharge light-source. Typical baseline technologies include metal halide (MH) and high pressure sodium (HPS) lamps.

### Definition of Efficient Condition

The efficient condition is defined as an LED parking garage or canopy luminaire or retrofit kit. Eligible luminaires and retrofit kits must be listed on the DesignLights Consortium Qualified Products List[539].

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE* = *Actual Connected load of baseline fixture*
= *If the actual baseline fixture wattage is unknown, use the default values presented in the "Parking Garage or Canopy Fixture Baseline and Efficient Wattage" table below.*
*WattsEE* = *Actual Connected load of the LED fixture*
= *If the actual LED fixture wattage is unknown, use the default values presented in the "Parking Garage or Canopy.*
*Fixture Baseline and Efficient Wattage" table below based on the based on the appropriate baseline description.*

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[539] DesignLights Consortium Qualified Products List <http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php>

**Parking Garage or Canopy Fixture Baseline and Efficient Wattage**[540]

| Measure Category | Baseline Description | WattsBASE | Efficient Description | WattsEE |
|---|---|---|---|---|
| LED Parking Garage/Canopy Fixture replacing up to 175W HID | 175W or less base HID | 171 | DLC Qualified LED Parking Garage and Canopy Luminaires | 94 |
| LED Parking Garage/Canopy Fixture replacing 176-250W HID | 176W up to 250W base HID | 288 | DLC Qualified LED Parking Garage and Canopy Luminaires | 162 |
| LED Parking Garage/Canopy Fixture replacing 251 and above HID | 251W and above base HID | 452 | DLC Qualified LED Parking Garage and Canopy Luminaires | 248 |

*HOURS = Deemed average hours of use per year*
*= 3,338 for canopy applications*[541] *and 8,678 for parking garage applications*[542]*.*
*ISR = In Service Rate or percentage of units rebated that get installed*
*= 1.00* [543]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

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[540] Baseline and efficient fixtures have been grouped into wattage categories based on typical applications. The typical baseline equipment in each group were weightings based on personal communication with Kyle Hemmi, CLEAResult on Sept. 18. 2012. Weighting reflects implementation program data from Texas, Nevada, Rocky Mountain, and Southwest Regions. When adequate program data is collected from the implementation of this measure in the Mid-Atlantic region, these weightings should be updated accordingly. Baseline fixture wattage assumptions developed from multiple TRMs including: Arkansas TRM Version 2.0, Volume 2: Deemed Savings, Frontier Associates, LLC, 2012; Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, 2012 Program Year – Plan Version, Massachusetts Electric and Gas Energy
Efficiency Program Administrators, 2011, and 2012 Statewide Customized Offering Procedures Manual for Business - Appendix B Table of Standard Fixture Wattages and Sample Lighting Table, Southern California Edison et al., 2012. As the total wattage assumptions for like fixture typically do not vary by more than a few watts between sources, the values from the Arkansas document have been adopted here. Efficient fixture wattage estimated assuming mean delivered lumen equivalence between the baseline and efficient case. Baseline initial lamp lumen output was reduced by estimates of lamp lumen depreciation and optical efficiency. Efficient wattage and lumen information was collected from appropriate product categories listed in the DesignLights Consortium Qualified Products List – Updated 11/21/2012. Analysis presented in the "Mid Atlantic C&I LED Lighting Analysis.xlsx" supporting workbook.

[541] Efficiency Vermont Technical Reference Manual 2009-55, December 2008; based on 5 years of metering on 235 outdoor circuits in New Jersey. Parking garages typically require artificial illumination 24 hours per day

[542] Navigant Commercial and Industrial Long Term Metering Study.

[543] Because of the comparatively high cost of LED equipment, it is likely that the ISR will be near 1.0. Additionally, it may be inappropriate to assume the "Equipment" category ISR from the EmPOWER Maryland DRAFT 2010 Interim Evaluation Report, Chapter 2: Commercial and Industrial Prescriptive, Navigant Consulting, 2010.

$$\Delta kWh = ((288 - 162) / 1000) * 8,678 * 1.00$$

$$= 1093 \text{ kWh}$$

### Summer Coincident Peak kW Savings Algorithm

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

*Where:*

*CF* = *Summer Peak Coincidence Factor for measure*

= *0 for canopy applications*[544] *and 0.98 for parking garage applications*[545]

Illustrative examples – do not use as default assumption

For example, a 250W parking garage standard metal halide fixture is replaced with an LED fixture:

$$\Delta kW = ((288 - 162) / 1000) * 1.00 * 0.98$$

$$= 0.12 \text{ kW}$$

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[546] hours. However, measure life is not to exceed 15 years[547].

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[544] It is assumed that efficient canopy lighting, when functioning properly, will never result in coincident peak demand savings.

[545] Navigant Commercial and Industrial Long Term Metering Study.

[546] Minimum DesignLights Consortium requirement is 50,000 hours for both parking garage and canopy luminaires. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[547] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# ENERGY STAR Integrated Screw Based SSL (LED) Lamp – Commercial

**Unique Measure Code: CI_LT_TOS_SSLDWN_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes savings from the purchase and installation of an ENERGY STAR Integrated Screw Based SSL (LED) Lamp V2.1 in place of an incandescent lamp.

### Definition of Baseline Condition

For time of sale replacement, the baseline wattage is assumed to be an incandescent or EISA complaint (where applicable) bulb installed in a screw-base socket.[548] Note that the baseline will be EISA compliant for all categories to which EISA applies. If the in situ lamp wattage is known and lower than the EISA mandated maximum wattage (where applicable), the baseline wattage should be assumed equal to the in situ lamp wattage.

### Definition of Efficient Condition

The high efficiency wattage is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. The ENERGY STAR specifications can be viewed here: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf

### Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

*Where:*

| | |
|---|---|
| *WattsBase* | = *Based on lumens of the LED – find the equivalent baseline wattage from the table below. For retrofit projects use in situ baseline.* In cases using assumed code minimum values, the TRM values below will be used instead. |
| *WattsEE* | = *Actual LED lamp watts.* |
| *HOURS* | = *Deemed average hours of use per year.*<br>= *See tables "C&I Downstream Lighting OpeParameters e" in Appendix D.* |
| *ISR* | = *In Service Rate or percentage of units rebated that are installed and operational* |

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

*= 1.00.* [549]

*WHFe* *= Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase | | |
|---|---|---|---|---|---|
| **Standard A-Type (medium-base)** | 250 | 449 | 25 | | |
| | 450 | 799 | 29 | | |
| | 800 | 1099 | 43 | | |
| | 1100 | 1599 | 53 | | |
| | 1600 | 1999 | 72 | | |
| | 2000 | 2599 | 72 | | |
| | 2600 | 3000 | 150 | | |
| | 3001 | 3999 | 200 | | |
| | 4000 | 6000 | 300 | | |
| **Decorative (medium-base, > 499 lumens)** | 500 | 1050 | 43 | | |
| **Globe (medium-base, > 499 lumens)** | 500 | 574 | 43 | | |
| | 575 | 649 | 53 | | |
| | 650 | 1099 | 72 | | |
| | 1100 | 1300 | 150 | | |
| **3-Way, bug, marine, rough service, infrared** | 250 | 449 | 25 | | |
| | 450 | 799 | 40 | | |
| | 800 | 1099 | 60 | | |
| | 1100 | 1599 | 75 | | |
| | 1600 | 1999 | 100 | | |
| | 2000 | 2549 | 125 | | |
| | 2550 | 2999 | 150 | | |
| **Globe**<br>(any base, < 500 lumens) | 90 | 179 | 10 | | |
| | 180 | 249 | 15 | | |

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[549] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

| | | | | | |
|---|---|---|---|---|---|
| | 250 | 349 | 25 | | |
| | 350 | 499 | 40 | | |
| **Globe (candelabra or intermediate base, ≥ 500 lumens)** | 500 | 574 | 60 | | |
| | 575 | 649 | 75 | | |
| | 650 | 1099 | 100 | | |
| | 1100 | 1300 | 150 | | |
| **Decorative**<br>(Shapes B, BA, C, CA, DC, F, G, any base, < 500 lumens) | 70 | 89 | 10 | | |
| | 90 | 149 | 15 | | |
| | 150 | 299 | 25 | | |
| | 300 | 500 | 40 | | |
| **Decorative (candelabra or intermediate base, ≥ 500 lumens)** | 500 | 1050 | 60 | | |
| **Reflector with medium screw bases w/ diameter <=2.25"** | 400 | 449 | 40 | | |
| | 450 | 499 | 45 | | |
| | 500 | 649 | 50 | | |
| | 650 | 1199 | 65 | | |
| **R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter >2.5" (*see exceptions below)** | 640 | 739 | 40 | | |
| | 740 | 849 | 45 | | |
| | 850 | 1179 | 50 | | |
| | 1180 | 1419 | 65 | | |
| | 1420 | 1789 | 75 | | |
| | 1790 | 2049 | 90 | | |
| | 2050 | 2579 | 100 | | |
| | 2580 | 3429 | 120 | | |
| | 3430 | 4270 | 150 | | |
| **R, PAR, ER, BR, BPAR or similar bulb shapes with medium screw bases w/ diameter > 2.26" and ≤ 2.5" (*see exceptions below)** | 540 | 629 | 40 | | |
| | 630 | 719 | 45 | | |
| | 720 | 999 | 50 | | |
| | 1000 | 1199 | 65 | | |
| | 1200 | 1519 | 75 | | |
| | 1520 | 1729 | 90 | | |
| | 1730 | 2189 | 100 | | |
| | 2190 | 2899 | 120 | | |
| | 2900 | 3850 | 150 | | |

| | | | | | |
|---|---|---|---|---|---|
| ***ER30, BR30, BR40, or ER40** | 400 | 449 | 40 | | |
| | 450 | 499 | 45 | | |
| | 500 | 649-1179[3] | 50 | | |
| ***BR30, BR40, or ER40** | 650 | 1419 | 65 | | |
| ***R20** | 400 | 449 | 40 | | |
| | 450 | 719 | 45 | | |
| ***All reflector lamps below lumen ranges specified above** | 200 | 299 | 20 | | |
| | 300 | 399-639[4] | 30 | | |

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

*Where:*

*0.7* = *Aspect ratio.* [550]
*0.003413* = *Constant to convert kWh to MMBTU.*
*0.23* = *Fraction of lighting heat that contributes to space heating.* [551]
*0.75* = *Assumed heating system efficiency.* [552]

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The table below shows the assumed measure life for ENERGY STAR Version 2.0:

| Lamp Type | ENERGY STAR V2.0[553] | |
|---|---|---|
| | Rated Life (Hours) | Measure Life (Years) |
| | | Commercial Interior |
| **Omnidirectional** | 15,000 | 4 |
| **Decorative** | 15,000 | 4 |
| **Directional** | 15,000[554] | 4 |

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

[551] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

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

[553] The v2.0 ENERGY STAR Product Specification for Lamps (Light Bulbs) requires rated life of 15,000 hours for solid-state omnidirectional and decorative lamps, and 25,000 hours for solid-state directional lamps. Measure lifetimes assume 3,500 average annual operating hours.

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

# Midstream Lighting – Commercial

**Unique Measure Code: CI_xx**
**Effective Date: xx**
**End Date: TBD**

### Measure Description

This measure describes savings from the purchase and installation of efficient lamps and luminaries obtained through the utilities' commercial midstream lighting program.

### Definition of Baseline Condition

For time of sale replacement, the baseline is assumed to be least expensive comparable lamp that meets code. For example, for most linear LED lamps, the baseline will be a corresponding T8 lamp. For screw-in lamps, the relevant EISA or EPCA code will be assumed.

### Definition of Efficient Condition

The high efficiency wattage for screw-in lamps is assumed to be an ENERGY STAR qualified Integrated Screw Based SSL (LED) Lamp. For linear lamps, assume measures consistent with either the four-foot LED or low wattage fluorescent measures below.

### Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) /1000) * HOURS * ISR * WHFe$$

*Where:*

*WattsBase* = *For screw-in LEDs, based on lumens of the LED – find the equivalent baseline wattage from the table below.For linear LEDs see the* four-foot LED or low wattage fluorescent measures below.
*WattsEE* = *Actual LED lamp watts.*
*HOURS* = *Deemed average hours of use per year.*
= *See tables "C&I Midstream Lighting OpeParameters e" in Appendix D.*
*ISR* = *In Service Rate or percentage of units rebated that are installed and operational*
= *1.00.* [555]
*WHFe* = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

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[555] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

**Base Watts for Midstream Lamps**

| Lamp Type | Lumens Min | Lumens Max | Baseline Wattage |
|---|---|---|---|
| LED Type A Lamp | 250 | 449 | 25 |
| | 450 | 799 | 29 |
| | 800 | 1099 | 43 |
| | 1100 | 1599 | 53 |
| | 1600 | 1999 | 72 |
| | 2000 | 2549 | 125 |
| | 2550 | 3000 | 150 |
| | 3001 | 3999 | 200 |
| | 4000 | 6000 | 300 |
| LED Candelabra Lamp | 70 | 89 | 10 |
| | 90 | 149 | 15 |
| | 150 | 299 | 25 |
| | 300 | 499 | 40 |
| | 500 | 1049 | 60 |
| LED MR, BR, PAR, R Lamp (Diameter of 30 or greater) | 200 | 299 | 20 |
| | 300 | 639 | 30 |
| | 640 | 739 | 40 |
| | 740 | 849 | 45 |
| | 850 | 1179 | 50 |
| | 1180 | 1419 | 65 |
| | 1420 | 1789 | 75 |
| | 1790 | 2049 | 90 |
| | 2050 | 2579 | 100 |
| | 2580 | 3429 | 120 |
| | 3430 | 4270 | 150 |
| LED MR, BR, PAR, R Lamp (Diameter less than 30) | 200 | 299 | 20 |
| | 300 | 399 | 30 |
| | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1199 | 65 |
| LED Type G Lamp: | 90 | 179 | 10 |

| | | | |
|---|---|---|---|
| | 180 | 249 | 15 |
| | 250 | 349 | 25 |
| | 350 | 499 | 40 |
| | 500 | 1049 | 60 |
| Small LED Recessed Trim Kits (Diameter less than 8") | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1419 | 65 |
| Large LED Recessed Trim Kits (Diameter 8" or more) | 400 | 449 | 40 |
| | 450 | 499 | 45 |
| | 500 | 649 | 50 |
| | 650 | 1419 | 65 |
| | 850 | 1179 | 50 |
| | 1180 | 1419 | 65 |
| | 1420 | 1789 | 75 |
| | 1790 | 2049 | 90 |
| | 2050 | 2579 | 100 |
| | 2580 | 3429 | 120 |
| | 3430 | 4270 | 150 |
| Reduced Wattage T8 Lamps | 1195 | 1380 | 17 |
| | 1929 | 2190 | 25 |
| | 2390 | 3010 | 32 |

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure*
= *See table "C&I Midstream Lighting Parameters" in Appendix D.*

## Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta \text{MMBTU} = (-\Delta \text{kWh} / \text{WHFe}) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta \text{kWh} / \text{WHFe}) * 0.00073$$

*Where:*

*0.7 = Aspect ratio.* [556]
*0.003413 = Constant to convert kWh to MMBTU.*
*0.23 = Fraction of lighting heat that contributes to space heating.* [557]
*0.75 = Assumed heating system efficiency.* [558]

## Annual Water Savings Algorithm

n/a

## Measure Life

For screw-in Lamps, the table below shows the assumed measure life for ENERGY STAR Version 2.0:

| Lamp Type | ENERGY STAR V2.0[559] | |
|---|---|---|
| | Rated Life (Hours) | Measure Life (Years) |
| | | Commercial Interior |
| **Omnidirectional** | 15,000 | 4 |
| **Decorative** | 15,000 | 4 |
| **Directional** | 15,000[560] | 4 |

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[556] 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.

[557] 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).

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

[559] The v2.0 ENERGY STAR Product Specification for Lamps (Light Bulbs) requires rated life of 15,000 hours for solid-state omnidirectional and decorative lamps, and 25,000 hours for solid-state directional lamps. Measure lifetimes assume 3,500 average annual operating hours.

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

For linear LED replacement lamps, the measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[561] hours. However, measure life is not to exceed 15 years[562].

For low wattage linear fluorescent lamps assume that the measure life is the rated life in hours of the actual fluorescent fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 24,000 hours.[563] However, measure life is not to exceed 15 years[564]

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[561] The minimum rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/14/2018 < https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/> is 50,000 hours for linear LED lamps.

[562] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

[563] The estimated lifetime for low wattage linear fluorescent lamps is 24,000 hours according to California DEERE's Remote Ex-Ante Database Interface (READI) v.2.4.7.

[564] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# LED Four-pin based Lamp – Commercial

**Unique Measure Code: CI_LT_TOS_LEDPL_0518, CI_LT_RF_LEDPL_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure describes savings from the purchase and installation of a 4-pin (LED) Lamp in place of a 4-pin CFL lamp.

### Definition of Baseline Condition

For time of sale replacement, the baseline is assumed to be a 4-pin CFL lamp. If the in-situ lamp wattage is known, the baseline wattage should be assumed equal to the in-situ lamp wattage.

### Definition of Efficient Condition

The high efficiency condition is a DesignLights Consortium[565] (DLC) qualified 4-pin LED lamp[566].

### Annual Energy Savings Algorithm

$$\Delta kWh = ((WattsBase - WattsEE) / 1000) * HOURS * ISR * WHFe$$

*Where:*

*WattsBase* = *Actual wattage of in-situ lamp. If unknown find the equivalent baseline wattage based on the LED initial lumen output from the table below.*

| Lower Lumen Range | Upper Lumen Range | WattsBase[567] |
|---|---|---|
| 760 | 934 | 13 |
| 935 | 1349 | 18 |
| 1350 | 1834 | 26 |
| 1835 | 2549 | 32 |
| 2550 | 3199 | 42 |

*WattsEE* = *Actual LED lamp rated watts.*

*HOURS* = *Deemed average hours of use per year.*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

*ISR* = *In Service Rate or percentage of units rebated that are installed and operational*
= *1.00.* [568]

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[565] https://www.designlights.org/

[566] DLC qualification is not required for LED lamps below 675 lumens.

[567] DOE and NREL TRM template for LED pin-base CFL replacements with input from stakeholders, "Tech to Utilities Draft Template_LED4Pin_20170919.xlxs"

[568] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*WHFd = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*
*CF = Summer Peak Coincidence Factor for measure*
*= See tables "C&I Downsteam Lighting Parameters" in Appendix D.*

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75$$
$$= (-\Delta kWh / WHFe) * 0.00073$$

*Where:*

*0.7 = Aspect ratio.* [569]
*0.003413 = Constant to convert kWh to MMBTU.*
*0.23 = Fraction of lighting heat that contributes to space heating.* [570]
*0.75 = Assumed heating system efficiency.* [571]

**Annual Water Savings Algorithm**

n/a

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[569] 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.

[570] 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).

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

**Measure Life**

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[572] hours. However, measure life is not to exceed 15 years[573].

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[572] Minimum DesignLights Consortium requirement. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[573] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# LED Refrigerated Case Lighting

**Unique Measure Code(s): CI_LT_TOS_LEDRCL_0518, CI_LT_RF_LEDRCL_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the installation of LED luminaries in vertical and horizontal refrigerated display cases replacing T8 or T12HO linear fluorescent lamp technology. Savings characterizations are provided for both coolers and freezers. Specified LED luminaires should meet v2.1 DesignLights Consortium Product Qualification Criteria for either the "Vertical Refrigerated Case Luminaire" or "Horizontal Refrigerated Case Luminaries" category. LED luminaires not only provide the same light output with lower connected wattages, but also produce less waste heat which decreases the cooling load on the refrigeration system and energy needed by the refrigeration compressor. Savings and assumptions are based on a pre linear foot of installed lighting basis.

### Definition of Baseline Condition

The baseline equipment is assumed to be T8 or T12HO linear fluorescent lamps.

### Definition of Efficient Condition

The efficient equipment is assumed to be DesignLights Consortium qualified LED vertical or horizontal refrigerated case luminaires.

### Annual Energy Savings Algorithm

ΔkWh = (WattsPerLFBASE – WattsPerLFEE) / 1000 * LF * HOURS * WHFe.

*Where:*

WattsPerLFBASE = Connected wattage per linear foot of the baseline fixtures; see table below for default values.[574]
WattsPerLFEE = Connected wattage per linear foot of the LED fixtures.[575]
= Actual installed. If actual installed wattage is unknown, see table below for default values.

| Efficient Lamp | Baseline Lamp | Efficient Fixture Wattage (WattsPerLFEE) | Baseline Fixture Watts (WattsPerLFBASE) |
|---|---|---|---|
| LED Case Lighting System | T8 Case Lighting System | 7.6 | 15.2 |

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[574] Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.
[575] Pacific Gas & Electric. May 2007. LED Refrigeration Case Lighting Workpaper 053007 rev1. Values normalized on a per linear foot basis.

| | | | |
|---|---|---|---|
| LED Case Lighting System | T12HO Case Lighting System | 7.7 | 18.7 |

LF = Linear feet of installed LED luminaires.
= Actual installed

HOURS = Deemed annual operating hours
= 6,205.[576]

WHFe = Waste heat factor for energy to account for refrigeration savings from efficient lighting. For prescriptive refrigerated lighting measures, the default value is 1.41 for refrigerated cases and 1.52 for freezer cases.[577]

### Summary Coincident Peak kW Savings Algorithm

$\Delta kW$ = (WattsPerLFBASE – WattsPerLFEE) / 1000 * LF * WHFd * CF.

*Where:*

*WHFd = Waste heat factor for demand to account for refrigeration savings from efficient lighting. For prescriptive refrigerated lighting measures, the default value is 1.40 for refrigerated cases and 1.51 for freezer cases.*[578]

*CF = Summer Peak Coincidence Factor for measure*
*= 0.96 (lighting in Grocery).*[579]

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[580] hours. However, measure life is not to exceed 15 years[581].

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[576] Theobald, M. A., Emerging Technologies Program: Application Assessment Report #0608, LED Supermarket Case Lighting Grocery Store, Northern California, Pacific Gas and Electric Company, January 2006. Assumes refrigerated case lighting typically operates 17 hours per day, 365 days per year.

[577] New York Department of Public Service. 2014. The New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-family, and Commercial/Industrial Measures Version 2.

[578] New York Department of Public Service. 2014. The New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-family, and Commercial/Industrial Measures Version 2.

[579] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014.

[580] Minimum DesignLights Consortium requirement. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[581] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# Exterior LED Flood and Spot Luminaires

**Unique Measure Code(s): CI_LT_TOS_LEDFLS_0518 and CI_LT_RF_LEDFLS_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure relates to the installation of an exterior LED flood or spot luminaire for landscape or architectural illumination applications in place of a halogen incandescent or high-intensity discharge light source. Eligible applications include time of sale and new construction as well as retrofit applications.

### Definition of Baseline Condition

The baseline condition is defined as an exterior flood or spot fixture with a high intensity discharge or PAR light-source. Typical baseline technologies include halogen incandescent parabolic aluminized reflector (PAR) lamps and metal halide (MH) luminaires.

### Definition of Efficient Condition

The efficient condition is defined as an LED flood or spot luminaire. Eligible luminaires must be listed on the DesignLights Consortium Qualified Products List[582].

### Annual Energy Savings Algorithm

$$\Delta \text{kWh} = ((\text{WattsBASE} - \text{WattsEE}) / 1000) * \text{HOURS}.$$

*Where:*

*WattsBASE = Actual Connected load of baseline fixture*
*= If the actual baseline fixture wattage is unknown, use the actual LED lumens to find equivalent baseline wattage from the table below.*[583]

| Bulb Type | Lower Lumen Range | Upper Lumen Range | WattsBase |
|---|---|---|---|
| **PAR38** | 500 | 1000 | 52.5 |
| | 1000 | 4000 | 108.7 |
| **Metal Halide** | 4000 | 15000[584] | 205.0 |
| **Metal Halide** | 15000 | 20000 | 288 |
| **Metal Halide** | 20000 | 30000 | 460 |

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[582] DesignLights Consortium Qualified Products List <https://www.designlights.org/qpl>

[583] Efficiency Vermont TRM User Manual No. 2014-85b; baseline are based on analysis of actual Efficiency Vermont installations of LED lighting. Exterior LED flood and spot luminaires are an evolving technology that may replace any number of baseline lamp and fixture types. It is recommended that programs track existing and new lamps and/or luminaire types, wattages, and lumen output in such way that baseline assumptions can be refined for future use.

[584] Source does not specify an upper lumen range for LED luminaires. Based on a review of manufacturer product catalogs, 15,000 lumens is the approximate initial lumen output of a 175W MH lamp.

*WattsEE* = *Actual Connected load of the LED luminaire.*
*HOURS* = *Deemed average hours of use per year.*
= *If annual operating hours are unknown, assume 3,604* [585].

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = ((WattsBASE - WattsEE) / 1000) * CF.$$

*Where:*

*CF* = *Summer Peak Coincidence Factor for measure*
= *0.11.* [586]

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

Measure life is the rated life in hours of the actual LED lamp divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[587] hours. However, measure life is not to exceed 15 years[588].

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[585] Navigant Commercial and Industrial Long Term Metering Study..

[586] Navigant Commercial and Industrial Long Term Metering Study.

[587] Minimum DesignLights Consortium requirement. <https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/>

[588] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# Low Wattage Four-Foot Linear Fluorescent Replacement Lamps

**Unique Measure Code(s): CI_LT_RF_FLTUBE_0420**
**Effective Date: M April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the replacement of four-foot linear fluorescent lamps with low wattage four-foot linear fluorescent replacement lamps, as offered through the midstream programs.

Measure eligibility is limited to midstream programs.

### Definition of Baseline Condition

The baseline condition is defined as an existing four-foot linear fluorescent fixture.

### Definition of Efficient Condition

The efficient condition is defined as a four-foot linear fluorescent fixture retrofitted with low wattage four-foot linear fluorescent replacement lamp(s).

### Annual Energy Savings Algorithm

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

*Where:*

*WattsBASE* = *28.2 W*
*WattsEE* = *Wattage of actual lamp installed; see table below*

**Default Lamp Wattage Assumptions**[589]

| Lamp/Ballast System | Per Lamp Wattage (W) |
|---|---|
| Assumed Baseline<br>32W T8 IS NLO | 28.2 |
| 28W T8 Premium PRS NLO | 24.6 |
| 25W T8 Premium PRS NLO | 22 |

*HOURS* = *Deemed average hours of use per year.*
= *See table "C&I Midstream Lighting Parameters" in Appendix D.*
*ISR* = *In Service Rate or percentage of units rebated that get installed.*
*WHFe* = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*

---

[589] Lamps assumed to be paired with a "normal ballast factor" ballast; ballast factor = 0.88. Note that this measure, presented on a per lamp basis, assumes no savings for reduced or eliminated ballast energy consumption.

*= HVAC type is unknown for midstream measures. WHFe = 1.0.*[590]

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If lights are claimed to be interior, assume the space is cooled and see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If lights are placed in exterior spaces, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure.*
= *See table "C&I Midstream Lighting Parameters" in Appendix D.*

**Annual Fossil Fuel Savings Algorithm**

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

ΔMMBTU = (-ΔkWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75 * HTM.
= (-ΔkWh / WHFe) * 0.00073.

*Where:*

*0.7* = *Aspect ratio.* [591]
*0.003413* = *Constant to convert kWh to MMBTU.*
*0.23* = *Fraction of lighting heat that contributes to space. heating* [592]
*0.75* = *Assumed heating system efficiency.* [593]
*HTM* = *Heat Type Multiplier. If the space is identified as exterior, HTM = 0. If the space is identified as interior, or unknown, HTM = 22.4% = 0.224*[594]

**Annual Water Savings Algorithm**

n/a

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[590] HVAC type is unknown for midstream measures. Territory includes both gas heat (WHFe > 1) and electric heat (WHFe < 1). Both heat types participate in the midstream program. An average WHFe of 1.0 is assumed.

[591] 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.

[592] 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).

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

[594] Based on all aggregated prescriptive lighting savings tracking data in 2017 in Maryland, of heated interior spaces, with reported interior or exterior data, 22.4% of interior savings were heated by fossil fuels and 77.6% were heated using some type of electricity as the primary fuel.

### Measure Life

Measure life is the rated life in hours of the actual fluorescent fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 24,000 hours.[595] However, measure life is not to exceed 15 years[596].

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[595] The estimated lifetime for low wattage linear fluorescent lamps is 24,000 hours according to California DEERE's Remote Ex-Ante Database Interface (READI) v.2.4.7.

[596] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# LED Four-Foot Linear Replacement Lamps

**0420**
**Effective Date: Ma April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the replacement of four-foot linear fluorescent lamps with tubular, LED four-foot linear replacement lamps. Depending on the specific LED replacement lamp product, this measure may require changing the electrical wiring, replacing the ballast with an external driver, or altering the existing lamp holders (or "tombstones") to accommodate the new lamp. Eligible applications are limited to retrofits. LED replacement lamp types are described in the table below:[597]

| LED Replacement Lamp Type | Description |
|---|---|
| Type A | The Type A lamp is designed with an internal driver that allows the lamp to operate directly from the existing linear fluorescent ballast. Most of these products are designed to work with T12, T8 and T5 ballasts. |
| Type B | The Type B lamp operates with an internal driver; however, the driver is powered directly from the main voltage supplied to the existing linear fluorescent fixture. |
| Type C | The Type C lamp operates with a remote driver that powers the LED linear lamp, rather than an integrated<br>driver. The Type B lamp involves electrical modification to the existing fixture, but the low-voltage outputs of the driver are connected to the sockets instead of line voltage. |

Measure eligibility is limited to "Type A" products that are powered by a new compatible T8 or T5 fluorescent electronic ballast installed at the same time as the LED replacement lamp or "Type C" products with an external LED driver.

All of the EmPOWER Maryland Utilities, no longer provide incentives for linear LED lamps with an internal driver connected directly to the line voltage (commonly referred to as "Type B.") This is due to the wide variety of installation characteristics of these types of lamps and the inherent safety concerns with these being powered directly from 120 – 277 voltage.

### Definition of Baseline Condition

The baseline condition is defined as an existing four-foot linear fluorescent fixture.

### Definition of Efficient Condition

The efficient condition is defined as a four-foot linear fluorescent fixture retrofit with LED four-foot linear replacement lamp(s) and, if required, external driver. Eligible LED replacement lamp

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[597] Underwriters Laboratories (UL) Standard 1598

fixture wattage must be less than the baseline fixture wattage and listed on the DesignLights Consortium (DLC) Qualified Products List[598].

**Annual Energy Savings Algorithm**

$$\Delta kWh = ((WattsBASE – WattsEE) / 1000) * HOURS * ISR * WHFe.$$

$$WattsEE = n * (WattsLAMP + AWPL).$$

*Where:*

*WattsBASE = Actual connected load of baseline fixture.*
*= If actual baseline wattage is unknown, assume the "WattsBASE" from the table below based on existing lamp/ballast system.*
*WattsEE = Actual connected load of the fixture with LED replacement lamps.*
*HOURS = Deemed average hours of use per year.*
*= See tables "C&I Downstream Lighting Parameters" in Appendix D.*
*ISR = In Service Rate or percentage of units rebated that get installed.*
*= 1.00.* [599]
*WHFe = Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*
*n = Number of Lamps*
*WattsLAMP = DLC reported wattage per lamp*[600]
*AWPL = Additional wattage per lamp resulting from ballast power consumption and ballast factor wattage manipulation. For LED T8 replacement lamps, use the table below. Use AWPL=0 for LED T5 replacement lamps.*

**Default Baseline Lamp Wattage Assumptions**[601]

| Baseline Lamp/Ballast System | Baseline Lamp Wattage (WattsBASE) |
|---|---|
| 32W T8 IS NLO | 29.5 |

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[598] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[599] Because of LED linear replacement lamps have not been specifically evaluated in the Mid-Atlantic region an initial ISR of 1.0 is assumed. However, costs of these products continue to drop rapidly increasing the probability that participants may purchase additional stock to be installed at a later date. This factor should be considered for future evaluation work.

[600] DesignLights Consortium Qualified Products List <http://www.designlights.org/QPL>

[601] California Technical Forum. February 2015. T8 LED Tube Lamp Replacement Abstract Revision # 0; Note that the "Delta Watts" values, presented on a per lamp basis, implicitly, and conservatively, assume no savings for reduced or eliminated ballast energy consumption.

| | |
|---|---|
| 28W T8 Premium PRS NLO | 25 |
| 25W T8 Premium PRS NLO | 22 |
| 28W T5 NLO[602] | 32 |

**LED T8[603] Additional Wattage per Lamp Assumptions[604]**

| **Number of Lamps in Fixture** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **Ballast Factor** | | | | |
| Low | -0.4 | -1.8 | -1.3 | -0.9 |
| Normal | 3.8 | 0.7 | 0.2 | -0.1 |
| High | 11.5 | 6.6 | 5.3 | 4.3 |
| Unknown | 4.2 | 0.9 | 0.4 | 0.1 |

### Summary Coincident Peak kW Savings Algorithm

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

*Where:*

*WHFd* = *Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
= *Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix E. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF* = *Summer Peak Coincidence Factor for measure.*
= *See tables "C&I Downstream Lighting Parameters" in Appendix D.*

### Annual Fossil Fuel Savings Algorithm

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHFe) * 0.70 * 0.003413 * 0.23 / 0.75.$$
$$= (-\Delta kWh / WHFe) * 0.00073.$$

*Where:*

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[602] The T5 wattage with ballast losses was sourced from: https://www.xcelenergy.com/staticfiles/xe/Marketing/MN-Bus-Lighting-Input-Wattage-Guide.pdf

[603] For LED T5 replacement lamps use AWPL=0.

[604] A Review of the Effects of Fluorescent Ballast Factors on Type A Linear LEDs, a 2019 special study, Navigant, December, 2019.

*0.7* = *Aspect ratio.* [605]
*0.003413* = *Constant to convert kWh to MMBTU.*
*0.23* = *Fraction of lighting heat that contributes to space. heating* [606]
*0.75* = *Assumed heating system efficiency.* [607]

**Annual Water Savings Algorithm**

n/a

**Measure Life**

Measure life is the rated life in hours of the actual LED fixture divided by the *average hours of use per year* (HOURS), and then rounded to the nearest whole number. If rated life is unknown, then assume 50,000[608] hours. However, measure life is not to exceed 15 years[609].

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[605] 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.

[606] 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).

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

[608] The minimum rated lifetime for applicable products on the DesignLights Consortium Qualified Products List – Updated 4/14/2018 < https://www.designlights.org/solid-state-lighting/qualification-requirements/technical-requirements/> is 50,000 hours for linear LED lamps.

[609] Even though the rated hours may last longer than 15 years, due to remodeling effects a maximum of 15 years is assumed.

# Networked Lighting Controls

**Unique Measure Code(s): CI_LT_RF_NLC_0619, CI_LT_NC_NLC_0619**
**Effective Date: June 2019**
**End Date: TBD**

### Measure Description

This measure defines the savings associated with installing a networked controlled lighting system. The control system must include luminaire-level lighting control (LLLC) that can switch lights on and off based on occupancy and is capable of full-range dimming based on local light levels. Note: Because networked lighting controls are required to include occupancy sensors and daylight harvesting, savings from occupancy sensors and daylight dimming control cannot be claimed separately. Additional savings may be achieved at no additional cost on a site-specific basis by implementing high-end trimming, personalized local controls, and customized scheduling with no need for additional equipment or software.

The analysis described in this measure is based on a study of multiple buildings and the associated savings is averaged by building type. On aggregate the calculated savings presented should agree with the average savings achieved on a program with multiple networked lighting controls projects but may not align with the savings achieved on an individual project. It is therefore recommended for large projects the analysis be handled with a custom calculation rather than the deemed savings presented here.

### Definition of Baseline Condition

The baseline condition is lighting that is controlled with a manual switch.

### Definition of Efficient Condition

The efficient condition is LLLC lighting that is controlled by a network system. Sensors must include occupancy and photo sensors, and the system must be able to dim or turn off individual fixtures based on local occupancy and light levels.

### Annual Energy Savings Algorithm

$$\Delta kWh = kW_{connected} * HOURS * (SVG – BLC) * ISR * WHF_e$$

*Where:*

$kW_{connected}$ *= kW lighting load connected to control.*
*HOURS = Deemed average hours of use per year.*
*= See tables "C&I Downstream Lighting Parameters" in Appendix D.*
*SVG = Percentage of annual lighting energy saved by lighting control; determined on a site-specific basis or using the default value based on building type from the table below.*[610]

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[610] Networked Lighting Control energy savings come from DLC report: Energy Savings from Networked Lighting Control (NLC) Systems, 2017.

| Building Type | Control Savings Factor (Energy)[611] |
|---|---|
| Assembly | 0.23 |
| Manufacturing | 0.30 |
| Office | 0.63 |
| School | 0.28 |
| Restaurant | 0.47 |
| Retail | 0.44 |
| Warehouse | 0.82 |
| Other | 0.47 |

*BLC* = *Baseline Lighting Control factor. See table below.*

| Installation Type | Baseline Lighting Control Factor |
|---|---|
| Retrofit – Space with pre-existing occupancy or photo sensors | 0.28 |
| Retrofit – Space with no pre-existing controls | 0.00 |
| New Construction – Space with occupancy sensors required by code[612] | 0.28 |
| New Construction – Occupancy sensors not required by code | 0.00 |

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

$WHF_e$ = *Waste Heat Factor for Energy to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table "Waste Heat Factors for C&I Lighting – Known HVAC Types" in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

**Summer Coincident Peak kW Savings Algorithm**

Lacking sufficient research to support unique peak demand savings calculations, the peak demand savings will conservatively be assumed to match those attributed to standard non-networked controls.

$$\Delta kW = kW_{connected} * (SVG - BLC) * ISR * WHF_d * CF$$

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[611] Findings from Networked Lighting Control energy savings come from DLC report: Energy Savings from Networked Lighting Control (NLC) Systems, 2017 modified to reflect Mid-Atlantic metering study lighting baseline hours of use. This change supported by NLC – LRC Literature Review, dated November 19, 2015.

[612] See local appropriate code documentation for occupancy sensor requirements.

*Where:*

*$WHF_d$ = Waste Heat Factor for Demand to account for cooling and heating impacts from efficient lighting.*
*= Varies by utility, building type, and HVAC equipment type. If HVAC type is known, see table “Waste Heat Factors for C&I Lighting – Known HVAC Types” in Appendix D. If HVAC type is unknown or the space is unconditioned, assume WHFe = WHFd = 1.0.*

*CF = Summer Peak Coincidence Factor for measure*
*= See tables “C&I Downstream Lighting Parameters” in Appendix D.*

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = (-\Delta kWh / WHF_e) * 0.003413 * 0.23 / 0.75$$
$$= -\Delta kWh * 0.00105$$

*Where:*

*0.003413 = Constant to convert kWh to MMBTU*
*0.23 = Fraction of lighting heat that contributes to space heating* [613]
*0.80 = Assumed heating system thermal efficiency* [614]

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 10 years.[615]

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[613] Fraction of lighting heat that contributes to space heating. Based on 0.23 factor for Washington DC (from 1993 ASHRAE Journal: Calculating Lighting and HVAC Interactions).

[614] Typical heating system thermal efficiency of 80%, consistent with minimum current federal standards for fossil fuel-fired systems.

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

*Heating Ventilation and Air Conditioning (HVAC) End Use*

# Unitary HVAC Systems

**Unique Measure Code(s): CI_HV_TOS_HVACSYS_0420 CI_HV_EREP_HVACSYS_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure documents savings associated with the installation of new heating, ventilating, and air conditioning systems exceeding baseline efficiency criteria in place of an existing system or a new standard efficiency system of the same capacity. This measure covers air conditioners (including unitary air conditioners and packaged terminal AC) and heat pumps (air source and packaged terminal heat pumps). It does not cover ductless mini-split units. This measure applies to time of sale, new construction, and early replacement opportunities.

### Definition of Baseline Condition

**Time of Sale or New Construction:** The baseline condition is a new system meeting minimum efficiency standards as presented in the 2012 International Energy Conservation Code (IECC 2012) and the 2015 International Energy Conservation Code (IECC 2015) (see table “Baseline Efficiencies by System Type and Unit Capacity” below)[616] or federal standards where more stringent than local energy codes. Note that due to federal standards scheduled to take effect on January 1, 2018, baseline requirements for some equipment classes differ over time.

**Early Replacement:** The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.

### Definition of Efficient Condition

The efficient condition is an HVAC system of the same type as the baseline system exceeding baseline efficiency levels.

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

**Baseline Efficiencies by System Type and Unit Capacity**

| Size Category (Cooling Capacity) | Subcategory | Baseline Condition (IECC 2012 or Federal Standard)[617] | Baseline Condition (IECC 2015 or Federal Standard) |
|---|---|---|---|
| **Air Conditioners, Air Cooled** | | | |
| <65,000 BTU/h | Split system | 13.0 SEER | 13.0 SEER |
| | Single package | 14.0 SEER | 14.0 SEER |
| ≥65,000 BTU/h and <135,000 BTU/h | Split system and single package | 11.3 EER<br>12.9 IEER | 11.3 EER<br>12.9 IEER |
| ≥135,000 BTU/h and <240,000 BTU/h | Split system and single package | 11.0 EER<br>12.4 IEER | 11.0 EER<br>12.4 IEER |
| ≥240,000 BTU/h and <760,000 BTU/h | Split system and single package | 10.0 EER<br>11.6 IEER | 10.0 EER<br>11.6 IEER |
| ≥760,000 BTU/h | Split system and single package | 9.7 EER<br>9.8 IEER | 9.7 EER<br>11.2 IEER |
| **Air Conditioners, Water Cooled** | | | |
| <65,000 BTU/h | Split system and single package | 12.1 EER<br>12.3 IEER | 12.1 EER<br>12.3 IEER |
| ≥65,000 BTU/h and <135,000 BTU/h | Split system and single package | 12.1 EER<br>12.3 IEER | 12.1 EER<br>13.9 IEER |
| ≥135,000 BTU/h and <240,000 BTU/h | Split system and single package | 12.5 EER<br>12.7 IEER | 12.5 EER<br>13.9 IEER |

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[617] Whichever requires a higher level of baseline efficiency IECC or Federal Standards.

The federal standards are provided by Energy Conservation Program for Certain Industrial Equipment: Energy Conservation Standards for Small, Large, and Very Large Air-Cooled Commercial Package Air Conditioning and Heating Equipment and Commercial Warm Air Furnaces; Final Rule, 81 Fed. Reg. 10 (January 15, 2016). Federal Register: The Daily Journal of the United States.

The federal standards do present EER requirements. The baseline requirements in the table are estimated based on the ratio of the EER and IEER values from IECC 2015 for the corresponding equipment category.

| | | | |
|---|---|---|---|
| ≥240,000 BTU/h and <760,000 BTU/h | Split system and single package | 12.4 EER<br>12.6 IEER | 12.4 EER<br>13.6 IEER |
| ≥760,000 BTU/h | Split system and single package | 12.0 EER<br>12.4 IEER | 12.2 EER<br>13.5 IEER |
| **Air Conditioners, Evaporatively Cooled** | | | |
| <65,000 BTU/h | Split system and single package | 12.1 EER<br>12.3 IEER | 12.1 EER<br>12.3 IEER |
| ≥65,000 BTU/h and <135,000 BTU/h | Split system and single package | 12.1 EER<br>12.3 IEER | 12.1 EER<br>12.3 IEER |
| ≥135,000 BTU/h and <240,000 BTU/h | Split system and single package | 12.0 EER<br>12.2 IEER | 12.0 EER<br>12.2 IEER |
| ≥240,000 BTU/h and <760,000 BTU/h | Split system and single package | 11.9 EER<br>12.1 IEER | 11.9 EER<br>12.1 IEER |
| ≥760,000 BTU/h | Split system and single package | 11.7 EER<br>11.9 IEER | 11.7 EER<br>11.9 IEER |
| **Heat Pumps, Air Cooled**[618] | | | |
| <65,000 BTU/h | Split System | 14.0 SEER<br>8.2 HSPF | 14.0 SEER<br>8.2 HSPF |
| | Single Package | 14.0 SEER<br>8.0 HSPF | 14.0 SEER<br>8.0 HSPF |
| ≥65,000 BTU/h and <135,000 BTU/h | Split system and single package | 11.2 EER<br>12.2 IEER<br>3.3 COP | 11.2 EER<br>12.2 IEER<br>3.3 COP |
| ≥135,000 BTU/h and <240,000 BTU/h | Split system and single package | 10.6 EER<br>11.6 IEER<br>3.2 COP | 10.6 EER<br>11.6 IEER<br>3.2 COP |
| ≥240,000 BTU/h and <760,000 BTU/h | Split system and single package | 9.5 EER<br>10.6 IEER<br>3.2 COP | 9.5 EER<br>10.6 IEER<br>3.2 COP |

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[618] Heating mode efficiencies for heat pumps >=65,000 BTU/h are provided at the 47°F db/43° wb outdoor air rating condition.

| Size Category (Cooling Capacity) | Subcategory | Baseline Condition (Federal Standards)[619] |
|---|---|---|
| **Packaged Terminal Air Conditioners[620,621]** | | |
| All Capacities | New Construction (Standard Size)[622] | 14.0 – (0.300 * Cap/1000) EER |
| All Capacities | Replacement (Non-Standard Size) | 10.9 – (0.213 * Cap/1000) EER |
| **Packaged Terminal Heat Pumps[623,624]** | | |
| All Capacities | New Construction (Standard Size) | 14.0 – (0.300 * Cap/1000) EER<br>3.7 – (0.052 * Cap/1000) COP |
| All Capacities | Replacement (Non-Standard Size) | 10.8 – (0.213 * Cap/1000) EER<br>2.9 – (0.026 * Cap/1000) COP |

Notes: 1) All cooling mode efficiency ratings in the table above assume electric resistance heating section type (or none). Subtract 0.2 from each baseline efficiency rating value if unit has heating section other than electric resistance.

### Annual Energy Savings Algorithm

#### Air Conditioners (includes air-, water-, and evaporatively-cooled unitary ACs and PTACs)

Time of Sale:

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

[620] Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

[621] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations.

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

[623] Replacement unit shall be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY: NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches (406 mm) in height and less than 42 inches (1067 mm) in width.

[624] "Cap" = The rated cooling capacity of the project in BTU/h. If the unit's capacity is less than 7,000 BTU/h, use 7,000 BTU/h in the calculation. If the unit's capacity is greater than 15,000 BTU/h, use 15,000 BTU/h in the calculations.

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$$\Delta kWh \quad = (BTU/h_{COOL}/1000) * ((1/SEERBASE) - (1/SEEREE)) * EFLH_{COOL}.$$

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (EER) as follows:

$$\Delta kWh \quad = (BTU/h_{COOL}/1000) * ((1/IEERBASE) - (1/IEEREE)) * EFLH_{COOL}.$$

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

$$\Delta kWh = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * EFLH_{COOL.}$$

Early Replacement[625]:

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) as follows:

$\Delta$kWh for remaining life of existing unit:

$$= (BTU/h_{COOL}/1000) * ((1/SEEREXIST) - (1/SEEREE)) * EFLH_{COOL}.$$

$\Delta$kWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (BTU/h_{COOL}/1000) * ((1/SEERBASE) - (1/SEEREE)) * EFLH_{COOL}.$$

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (IEER) as follows:

$\Delta$kWh for remaining life of existing unit:

$$= (BTU/h_{COOL}/1000) * ((1/IEEREXIST) - (1/IEEREE)) * EFLH_{COOL}.$$

$\Delta$kWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= (BTU/h_{COOL}/1000) * ((1/IEERBASE) - (1/IEEREE)) * EFLH_{COOL}.$$

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

$\Delta$kWh for remaining life of existing unit:

$$= (BTU/h_{COOL}/1000) * ((1/EEREXIST) - (1/EEREE)) * EFLH_{COOL.}$$

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[625] The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

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

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

**Heat Pumps (includes air-source HPs and PTHPs)**

Time of Sale:

For units with capacities less than 65,000 BTU/h (except PTHPs), the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) and Heating Season Performance (HSPF) as follows:

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEERBASE) – (1/SEEREE)) * EFLH_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPFBASE) – (1/HSPFEE)) * EFLH_{HEAT.}$

For units with capacities greater than or equal to 65,000 BTU/h (except PTHPs), the energy savings are calculated using the Integrated Energy Efficiency Ratio (IEER) and Coefficient of Performance (COP) as follows:

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEERBASE) – (1/IEEREE)) * EFLH_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * EFLH_{HEAT.}$

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

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

Early Replacement[626]:

For units with capacities less than 65,000 BTU/h, the energy savings are calculated using the Seasonal Energy Efficiency Ratio (SEER) and Heating Season Performance (HSPF) as follows:

ΔkWh for remaining life of existing unit:

$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEEREXIST) – (1/SEEREE)) * EFLH_{COOL.}$

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[626] The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPFEXIST) – (1/HSPFEE)) * EFLH_{HEAT.}$

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

$\Delta kWh \quad = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/SEERBASE) – (1/SEEREE)) * EFLH_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/1000) * ((1/HSPFBASE) – (1/HSPFEE)) * EFLH_{HEAT.}$

For units with capacities greater than or equal to 65,000 BTU/h, the energy savings are calculated using the Integrated Energy Efficiency Ratio (EER) and Coefficient of Performance (COP) as follows:

ΔkWh for remaining life of existing unit:

$\Delta kWh \quad = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEEREXIST) – (1/IEEREE)) * EFLH_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEXIST) – (1/COPEE)) * EFLH_{HEAT.}$

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

$\Delta kWh \quad = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/IEERBASE) – (1/IEEREE)) * EFLH_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPBASE) – (1/COPEE)) * EFLH_{HEAT.}$

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

ΔkWh for remaining life of existing unit:

$\Delta kWh \quad = \Delta kWh_{COOL} + \Delta kWh_{HEAT.}$
$\Delta kWh_{COOL} = (BTU/h_{COOL}/1000) * ((1/EEREXIST) – (1/EEREE)) * EFLH_{COOL.}$
$\Delta kWh_{HEAT} = (BTU/h_{HEAT}/3412) * ((1/COPEXIST) – (1/COPEE)) * EFLH_{HEAT}$

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

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

*Where:*

$\Delta kWh_{COOL}$ = Annual cooling season electricity savings (kWh).
$\Delta kWh_{HEAT}$ = Annual heating season electricity savings (kWh).
*$BTU/h_{COOL}$ = Cooling capacity of equipment in BTU/hour.*
*= Actual Installed.*
*$BTU/h_{HEAT}$ = Heating capacity of equipment in BTU/hour.*
*= Actual Installed.*
*SEEREE = SEER of efficient unit.*
*= Actual Installed.*

*SEERBASE = SEER of baseline unit.*
*= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.*
*SEEREXIST = SEER of the existing unit.*
*= Actual.*
*HSPFEE = HSPF of efficient unit.*
*= Actual Installed.*
*HSPFBASE = HSPF of baseline unit.*
*= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.*
*HSPFEXIST = HSPF of the existing unit.*
*= Actual.*
*IEEREE = IEER of efficient unit.*
*= Actual Installed.*
*IEERBASE = IEER of baseline unit.*
*= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.*
*IEEREXIST = IEER of the existing unit.*
*= Actual.*
*COPEE = COP of efficient unit.*
*= Actual Installed.*
*COPBASE = COP of baseline unit.*
*= Based on IECC 2012 or IECC 2015 for the installed capacity. See table above.*
*COPEXIST = COP of the existing unit.*
*= Actual.*
*EERBASE = EER of baseline unit.*
*= Based on IECC 2012 or 2015 for the installed capacity. See table above.*
*EEREE = EER of efficient unit (If the actual EER is unknown, it may be approximated by using the following equation: EER = SEER/1.2)*
*= Actual installed.*
*EEREXIST = EER of existing unit.*
*= Actual.*
*3412 = Conversion factor (BTU/kWh).*
$EFLH_{COOL}$ *= Full load cooling hours.*[627]
*= If actual full load cooling hours are unknown, see table "Full Load Cooling Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load cooling hours information.*
$EFLH_{HEAT}$ *= Full load heating hours.*
*= If actual full load heating hours are unknown, see table "Full Load Heating Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load heating hours information.*

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[627] From U.S. DOE. 2013. *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*: "Although the EFLH is calculated with reference to a peak kW derived from EER, it is acceptable to use these EFLH with SEER or IEER. Some inconsistency occurs in using full-load hours with efficiency ratings measured at part loading, but errors in calculation are thought to be small relative to the expense and complexity of developing hours-of-use estimates precisely consistent with SEER and IEER."

### Summer Coincident Peak kW Savings Algorithm

Time of Sale:

$\Delta kW = (BTU/h_{COOL}/1000) * ((1/EERBASE) - (1/EEREE)) * CF.$

Early Replacement:

ΔkW for remaining life of existing unit:

$= (BTU/h_{COOL}/1000) * ((1/EEREXIST) – (1/EEREE)) * CF.$

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

$= (BTU/h_{COOL}/1000) * ((1/EERBASE) – (1/EEREE)) * CF.$

*Where:*

$CF_{PJM}$ = *PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather*
*= 0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.*[628]

$CF_{UPeak}$ = *Utility Peak Coincidence Factor (hour ending 5pm on hottest summer weekday).*
*= 0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.*[629]

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 15 years.[630]

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

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

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

# Ductless Mini-Split Heat Pump (DMSHP)

**Unique Measure Code(s): CI_HV_TOS_DMSHP_0420, CI_HV_EREP_DMSHP_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of new ENERGY STAR rated ductless “mini-split” heat pump(s) (DMSHP). A ductless mini-split heat pump is a type of heat pump with an outdoor condensing unit connected via refrigerant line to one or more indoor evaporator coils. Ductless mini-split heat pumps deliver cooling at the same or higher efficiency as standard central AC units, but can also deliver heat. Further, since the units do not require ductwork, they avoid duct losses.

### Definition of Baseline Condition

This measure assumes installation in a small commercial space.

**Time of Sale or New Construction:** Since the efficient unit is unducted, it is assumed that the baseline equipment will also be unducted. In such cases, or if the baseline condition for an early replacement is unknown, it is assumed that the baseline equipment is a window AC unit with a gas hot water boiler feeding hot water baseboards. The assumed baseline efficiency is that of equipment minimally compliant federal efficiency standards.

**Early Replacement:** The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.[631] If the space is currently uncooled, it is assumed that the building owner would have installed cooling by other means and should therefore be treated as a lost opportunity measure with a window AC baseline.

### Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified ductless mini-split heat pump, with a minimum 15 SEER, 12.0 EER, and 8.5 HSPF. If the rated efficiency of the actual unit is higher than the ENERGY STAR minimum requirements, the actual efficiency ratings should be used in the calculation.

### Baseline and Efficient Levels by Unit Capacity

If the measure is a retrofit, the actual efficiencies of the baseline heating and cooling equipment should be used. If it is a market opportunity, the baseline efficiency should be selected from the tables below.

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[631] To enable improvements to this measure characterization in the future, the existing equipment types should be tracked by the program to ensure that this measure characterizes the appropriate baseline conditions.

**Baseline Window AC Efficiency**[632]

| Equipment Type | Capacity (BTU/h) | Federal Standard with louvered sides (CEER) | Federal Standard without louvered sides (CEER) |
|---|---|---|---|
| Without Reverse Cycle | < 8,000 | 11.0 | 10.0 |
| | 8,000 to 10,999 | 10.9 | 9.6 |
| | 11,000 to 13,999 | 10.9 | 9.5 |
| | 14,000 to 19,999 | 10.7 | 9.3 |
| | 20,000 to 24,999 | 9.4 | 9.4 |
| With Reverse Cycle | <14,000 | 9.8 | 9.3 |
| | 14,000 to 19,999 | 9.8 | 8.7 |
| | >=20,000 | 9.3 | 8.7 |
| Casement-Only | All | 9.5 | |
| Casement-Slider | All | 10.4 | |

**Baseline Central AC Efficiency**

| Equipment Type | Capacity (BTU/h) | SEER | EER |
|---|---|---|---|
| Split System Air Conditioners[633] | All | 13 | 11.2 |
| Packaged Air Conditioners[634] | All | 14 | 11.8 |
| Packaged Air Source Heat Pumps[635] | All | 14 | 11.8 |

**Baseline Heating System Efficiency**

| Equipment Type | Efficiency Metric | Efficiency |
|---|---|---|
| Gas Boiler[636] | AFUE | 82% |
| Air Source Heat Pump – Split System[637] | HSPF | 8.2 |
| Air Source Heat Pump - Packaged | HSPF | 8.0 |
| Electric Resistance[638] | HSPF | 3.41 |

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[632] Federal standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41

[633] Federal Standard as of January 1, 2015. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75

[634] Ibid.

[635] Ibid

[636] Federal Standards for gas boilers

[637] Federal standards for air source heat pumps

[638] Electric heat has a COP of 1.0. Converted into HSPF units this is approximately 3.41.

## Annual Energy Savings Algorithm

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

$$\Delta kWh_{cool} = CCAP \times (1/SEER_{base} – 1/SEER_{ee}) \times EFLH_{cool}.$$

$$\Delta kWh_{heat}{}^{639} = HCAP \times (ELECHEAT/HSPF_{base} – 1/HSPF_{ee}) \times EFLH_{heat}.$$

*Where:*

*CCAP = Cooling capacity of DMSHP unit, in kBTU/hr.*

*$SEER_{base}$ = SEER of baseline unit. If unknown, use 9.8*[640]*.*

*$SEER_{ee}$ = SEER of actual DMSHP. If unknown, use ENERGYSTAR minimum of 15.*

*$EFLH_{cool}$ = Full load hours for cooling equipment.*

*= If actual full load cooling hours are unknown, see table "Full Load Cooling Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load cooling hours information.*

*HCAP = Heating capacity of DMSHP unit, in kBTU/hr.*

*ELECHEAT = 1 if the baseline is electric heat, 0 otherwise. If unknown, assume the baseline is a gas boiler, so ELECHEAT = 0.*

*$HSPF_{base}$ = HSPF of baseline equipment. See table above.*[641]

*$HSPF_{ee}$ = HSPF of actual DMSHP. If unknown, 8.5.*

*$EFLH_{heat}$ = Full load hours for heating equipment.*

*= If actual full load heating hours are unknown, see table "Full Load Heating Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load heating hours information.*

## Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = CCAP \times (1/EER_{base} – 1/EER_{ee}) \times CF.$$

*Where:*

*$EER_{base}$ =EER of baseline unit. If unknown, use 9.8*[642]*.*

*$EER_{ee}$ =EER of actual DMSHP. If unknown, use ENERGY STAR minimum of 12.0.*

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

*= 0.360 for units <135 kBTU/h and 0.567 for units ≥135*

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[639] This will be negative if the baseline has non-electric heat. This is because some electricity from the DMSHP is now assumed to be used for space heating. There us a corresponding savings in fossil fuel heat.

[640] Federal standard for typical window AC sizes with louvered sides.

[641] If unknown, assume the baseline is a gas furnace, with no electrical savings

[642] Federal standard for typical window AC sizes with louvered sides.

*kBTU/h.*[643]

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

*= 0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.*[644]

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBTU = HCAP \times EFLH_{heat} / AFUE / 1{,}000$$

*Where:*

*$EFLH_{heat}$ = Full load hours for heating equipment. See table above.*

*AFUE = AFUE of baseline equipment. If unknown use 82%.*[645]

**Measure Life**

The measure life for a DSMHP is 18 years.[646]

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

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

[645] Federal standard for gas boilers.

[646] GDS Associates, Inc. (2007). *Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures*. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

# Variable Frequency Drive (VFD) for HVAC

**Unique Measure Code(s): CI_MO_RF_VFDRIVE_0518**
**Effective Date: May 2018**
**End Date: TBD**

### Measure Description

This measure defines savings associated with installing a variable frequency drive on a motor of 200 hp or less for the following HVAC applications: supply fans, return fans, exhaust fans, chilled water pumps, and heating hot water pumps. The fan or pump speed will be controlled to maintain the desired system pressure. The application must have a load that varies and proper controls (i.e., Two–way valves, VAV boxes) must be installed. Pump VFDs should be analyzed using a custom approach wherever possible given the variability of the energy and demand saving factors. Non-HVAC VFDs should be evaluated using a custom approach, and this VFD for HVAC measure is not applicable to non-HVAC applications.

### Definition of Baseline Condition

The baseline condition is a motor, 200 hp or less, without a VFD control.

### Definition of Efficient Condition

The efficient condition is a motor, 200 hp or less, with a VFD control.

### Annual Energy Savings Algorithm[647]

### HVAC Fan Applications

$$\Delta kWh = \Delta kWh_{FAN} * (1 + IE_{ENERGY})$$

$$\Delta kWh_{FAN} = kWh_{BASE} - kWh_{RETRO}$$

$$kWh_{BASE} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}}\right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{BASE})$$

$$kWh_{RET} = \left(0.746 * HP * \frac{LF}{\eta_{MOTOR}}\right) * RHRS_{BASE} * \sum_{0\%}^{100\%} (\%FF * PLR_{RET})$$

*Where:*

$\Delta kWh_{FAN}$ = *Fan-only annual energy savings.*

$IE_{ENERGY}$ = *HVAC interactive effects factor for energy*

= *Assume 0%.*[648]

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[647] Unless otherwise noted, savings characterization and associated parameters adopted from Del Balso, R., and K. Monsef. "Investigation into the Reliability of Energy Efficiency/Demand Side Management Savings Estimates for Variable Frequency Drives in Commercial Applications", University of Colorado, Department of Civil, Environmental and Architectural Engineering, 2013.

[648] Del Balso, R., and K. Monsef, 2013 notes that the default HVAC interactive effects factor presented in the paper, 15.7%, "should not be used for actual program implementation, but such a factor should be developed and used based on a more complete set of energy modeling results for a given jurisdiction." A value of zero should be assumed, essentially omitting interactive effects, until a jurisdiction-specific analysis can be performed.

*$\Delta kWh_{FAN}$* = *Baseline annual energy consumption (kWh/yr).*
*$\Delta kWh_{RETRO}$* = *Retrofit annual energy consumption (kWh/yr).*
*0.746* = *Conversion factor for hp to kWh.*
*HP* = *Nominal horsepower of controlled motor.*
= *Actual.*
*LF* = *Load Factor; Motor Load at Fan Design CFM.*
= *If actual load factor is unknown, assume 65%.*
*$\eta_{MOTOR}$* = *Installed nominal/nameplate motor efficiency.*
= *Actual efficiency.*
*$RHRS_{BASE}$* = *Annual operating hours for fan motor based on building type.*
= *If actual hours are unknown, assume defaults in VFD Operating Hours by Application and Building Type table below.*
*%FF* = *Percentage of run-time spent within a given flow fraction range.*
= *If actual values unknown, see Default Fan Duty Cycle table below for default values.*

**Default Fan Duty Cycle**

| Flow Fraction (% of design cfm) | Percent of Time at Flow Fraction (%FF) |
|---|---|
| 0% to 10% | 0.0% |
| 10% to 20% | 1.0% |
| 20% to 30% | 5.5% |
| 30% to 40% | 15.5% |
| 40% to 50% | 22.0% |
| 50% to 60% | 25.0% |
| 60% to 70% | 19.0% |
| 70% to 80% | 8.5% |
| 80% to 90% | 3.0% |
| 90% to 100% | 0.5% |

*$PLR_{BASE}$* = *Part load ratio for a given flow fraction range based on the baseline flow control type.*
*$PLR_{RETRO}$* = *Part load ratio for a given flow fraction range based on the retrofit flow control type.*

**Part Load Ratios by Control and Fan Type and Flow Fraction (PLR)**

| Control Type | Flow Fraction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| No Control or Bypass Damper | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Discharge Dampers | 0.46 | 0.55 | 0.63 | 0.70 | 0.77 | 0.83 | 0.88 | 0.93 | 0.97 | 1.00 |
| Outlet Damper, BI & Airfoil Fans | 0.53 | 0.53 | 0.57 | 0.64 | 0.72 | 0.80 | 0.89 | 0.96 | 1.02 | 1.05 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Inlet Damper Box | 0.56 | 0.60 | 0.62 | 0.64 | 0.66 | 0.69 | 0.74 | 0.81 | 0.92 | 1.07 |
| Inlet Guide Vane, BI & Airfoil Fans | 0.53 | 0.56 | 0.57 | 0.59 | 0.60 | 0.62 | 0.67 | 0.74 | 0.85 | 1.00 |
| Inlet Vane Dampers | 0.38 | 0.40 | 0.42 | 0.44 | 0.48 | 0.53 | 0.60 | 0.70 | 0.83 | 0.99 |
| Outlet Damper, FC Fans | 0.22 | 0.26 | 0.30 | 0.37 | 0.45 | 0.54 | 0.65 | 0.77 | 0.91 | 1.06 |
| Eddy Current Drives | 0.17 | 0.20 | 0.25 | 0.32 | 0.41 | 0.51 | 0.63 | 0.76 | 0.90 | 1.04 |
| Inlet Guide Vane, FC Fans | 0.21 | 0.22 | 0.23 | 0.26 | 0.31 | 0.39 | 0.49 | 0.63 | 0.81 | 1.04 |
| VFD with duct static pressure controls | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 0.29 | 0.41 | 0.57 | 0.76 | 1.01 |
| VFD with low/no duct static pressure (<1" w.g.) | 0.05 | 0.06 | 0.09 | 0.12 | 0.18 | 0.27 | 0.39 | 0.55 | 0.75 | 1.00 |

**HVAC Pump Applications**

$$\Delta kWh = ((HP * 0.746 * LF) / \eta_{MOTOR}) * RHRS_{BASE} * ESF$$

*Where:*

*HP* = *Nominal horsepower of controlled motor.*
= *Actual.*
*0.746* = *Conversion factor for hp to kWh.*
*LF* = *Load Factor; Motor Load at Pump Design flow rate.*
= *If actual load factor is unknown, assume 65%.*
$\eta_{MOTOR}$ = *Installed nominal/nameplate motor efficiency.*
= *Actual efficiency.*
$RHRS_{BASE}$ = *Annual operating hours for pump motor based on building type.*
= *If actual hours are unknown, assume defaults in VFD Operating Hours by Application and Building Type table below.*
*ESF* = *Energy Savings Factor (see table "Energy and Demand Savings Factors" below).*

**Summer Coincident Peak kW Savings Algorithm**

**HVAC Fan Applications**

$$\Delta kW = \Delta kW_{FAN} * (1 + IE_{DEMAND}).$$
$$\Delta kW_{FAN} = \Delta kW_{BASE} - \Delta kW_{RETRO.}$$
$$\Delta kW_{BASE} = (0.746 * HP * LF / \eta_{MOTOR}) * PLR_{BASE,\ PEAK.}$$
$$\Delta kW_{RETRO} = (0.746 * HP * LF / \eta_{MOTOR}) * PLR_{RETRO,\ PEAK.}$$

*Where:*

*$\Delta kW_{FAN}$ = Fan-only annual demand savings (kW).*
*$IE_{DEMAND}$ = HVAC interactive effects factor for demand.*
*= If unknown, assume 0%.*[649]
*$\Delta kW_{FAN}$ = Baseline summer coincident peak demand (kW).*
*$\Delta kW_{RETRO}$ = Retrofit summer coincident peak demand (kW).*
*$PLR_{BASE, PEAK}$ = PLR for the average flow fraction during summer peak period for baseline flow control type (default average flow fraction during peak period = 100 %).*
*$PLR_{RETRO, PEAK}$ = PLR for the average flow fraction during summer peak period for retrofit flow control type (default average flow fraction during peak period = 100%).*

**HVAC Pump Applications**

$$\Delta kW = ((HP * 0.746 * LF) / \eta_{MOTOR}) * DSF * CF.$$

*Where:*
*DSF = Demand Savings Factor (see table "Energy and Demand Savings Factors" below).*
*CF = Summer Peak Coincidence Factor for measure*
*= 0.55.* [650]

**VFD Operating Hours by Application and Building Type ($RHRS_{BASE}$)[651]**

| Facility Type | Fan Motor Hours | Chilled Water Pumps | Heating Pumps |
|---|---|---|---|
| Auto Related | 4,056 | 1,878 | 5,376 |
| Bakery | 2,854 | 1,445 | 5,376 |
| Banks, Financial Centers | 3,748 | 1,767 | 5,376 |
| Church | 1,955 | 1,121 | 5,376 |
| College – Cafeteria | 6,376 | 2,713 | 5,376 |
| College - Classes/Administrative | 2,586 | 1,348 | 5,376 |
| College - Dormitory | 3,066 | 1,521 | 5,376 |
| Commercial Condos | 4,055 | 1,877 | 5,376 |
| Convenience Stores | 6,376 | 2,713 | 5,376 |
| Convention Center | 1,954 | 1,121 | 5,376 |
| Court House | 3,748 | 1,767 | 5,376 |

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[649] Del Balso, R., and K. Monsef, 2013 notes that the default HVAC interactive effects factor presented in the paper, 15.7%, "should not be used for actual program implementation, but such a factor should be developed and used based on a more complete set of energy modeling results for a given jurisdiction." A value of zero should be assumed, essentially omitting interactive effects, until a jurisdiction-specific analysis can be performed.

[650] UI and CL&P Program Saving Documentation for 2009 Program Year, Table 1.1.1; HVAC - Variable Frequency Drives – Pumps.

[651] United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8th Edition for 2013 Program Year. Orange, CT. For values marked with an asterisk (*), values adapted from Pennsylvania PUC. 2016. *Technical Reference Manual* and scaled based on heating degree days.

| Facility Type | Fan Motor Hours | Chilled Water Pumps | Heating Pumps |
|---|---|---|---|
| Dining: Bar Lounge/Leisure | 4,182 | 1,923 | 5,376 |
| Dining: Cafeteria / Fast Food | 6,456 | 2,742 | 5,376 |
| Dining: Family | 4,182 | 1,923 | 5,376 |
| Entertainment | 1,952 | 1,120 | 5,376 |
| Exercise Center | 5,836 | 2,518 | 5,376 |
| Fast Food Restaurants | 6,376 | 2,713 | 5,376 |
| Fire Station (Unmanned) | 1,953 | 1,121 | 5,376 |
| Food Stores | 4,055 | 1,877 | 5,376 |
| Gymnasium | 2,586 | 1,348 | 5,376 |
| Hospitals | 7,674 | 3,180 | 8,760* |
| Hospitals / Health Care | 7,666 | 3,177 | 8,760* |
| Industrial - 1 Shift | 2,857 | 1,446 | 5,376 |
| Industrial - 2 Shift | 4,730 | 2,120 | 5,376 |
| Industrial - 3 Shift | 6,631 | 2,805 | 5,376 |
| Laundromats | 4,056 | 1,878 | 5,376 |
| Library | 3,748 | 1,767 | 5,376 |
| Light Manufacturers | 2,857 | 1,446 | 5,376 |
| Lodging (Hotels/Motels) | 3,064 | 1,521 | 5,942* |
| Mall Concourse | 4,833 | 2,157 | 5,376 |
| Manufacturing Facility | 2,857 | 1,446 | 5,376 |
| Medical Offices | 3,748 | 1,767 | 5,376 |
| Motion Picture Theatre | 1,954 | 1,121 | 5,376 |
| Multi-Family (Common Areas) | 7,665 | 3,177 | 5,376 |
| Museum | 3,748 | 1,767 | 5,376 |
| Nursing Homes | 5,840 | 2,520 | 5,428* |
| Office (General Office Types) | 3,748 | 1,767 | 3,038* |
| Office/Retail | 3,748 | 1,767 | 3,038* |
| Parking Garages & Lots | 4,368 | 1,990 | 5,376 |
| Penitentiary | 5,477 | 2,389 | 5,376 |
| Performing Arts Theatre | 2,586 | 1,348 | 5,376 |
| Police / Fire Stations (24 Hr) | 7,665 | 3,177 | 5,376 |
| Post Office | 3,748 | 1,767 | 5,376 |
| Pump Stations | 1,949 | 1,119 | 5,376 |
| Refrigerated Warehouse | 2,602 | 1,354 | 0 |
| Religious Building | 1,955 | 1,121 | 5,376 |
| Residential (Except Nursing Homes) | 3,066 | 1,521 | 5,376 |
| Restaurants | 4,182 | 1,923 | 5,376 |
| Retail | 4,057 | 1,878 | 2,344* |
| School / University | 2,187 | 1,205 | 4,038* |
| Schools (Jr./Sr. High) | 2,187 | 1,205 | 3,229* |
| Schools (Preschool/Elementary) | 2,187 | 1,205 | 3,229* |

| Facility Type | Fan Motor Hours | Chilled Water Pumps | Heating Pumps |
|---|---|---|---|
| Schools (Technical/Vocational) | 2,187 | 1,205 | 3,229* |
| Small Services | 3,750 | 1,768 | 5,376 |
| Sports Arena | 1,954 | 1,121 | 5,376 |
| Town Hall | 3,748 | 1,767 | 5,376 |
| Transportation | 6,456 | 2,742 | 5,376 |
| Warehouse (Not Refrigerated) | 2,602 | 1,354 | 5,376 |
| Waste Water Treatment Plant | 6,631 | 2,805 | 5,376 |
| Workshop | 3,750 | 1,768 | 5,376 |

a. Non-HVAC VFDs should be evaluated using a custom approach, as this VFD for HVAC measure is not applicable to non-HVAC applications.

### Energy and Demand Savings Factors[652]

| HVAC Pump VFD Savings Factors | | |
|---|---|---|
| **System** | **ESF** | **DSF** |
| Chilled Water Pump | 0.633 | 0.460 |
| Hot Water Pump | 0.652 | 0.000 |

a. Non-HVAC VFDs should be evaluated using a custom approach, as this VFD for HVAC measure is not applicable to non-HVAC applications.

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 15 years for HVAC applications.[653]

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[652] United Illuminating Company and Connecticut Light & Power Company. 2012. Connecticut Program Savings Document – 8th Edition for 2013 Program Year. Orange, CT; energy and demand savings constants were derived using a temperature bin spreadsheet and typical heating, cooling, and fan load profiles. Note, these values have been adjusted from the source data for remove the embedded load factor.

[653] Navigant. 2013. Incremental Cost Study Phase Two Final Report. Burlington, MA.

# Electric Chillers

**Unique Measure Code: CI_HV_TOS_ELCHIL_0420 CI_HV_EREP_ELCHIL_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a new high-efficiency electric water chilling package in place of an existing chiller or a new standard efficiency chiller of the same capacity. This measure applies to time of sale, new construction, and early replacement opportunities.

### Definition of Baseline Condition

**Time of Sale or New Construction**: For Washington, D.C. and Delaware, the baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2012 (IECC 2012), Table C403.2.3(7). For Maryland, the baseline condition is a standard efficiency water chilling package equal to the requirements presented in the International Energy Conservation Code 2015 (IECC 2015), Table C403.2.3(7).

**Early Replacement:** The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline as defined above for the remainder of the measure life.

### Definition of Efficient Condition

For Washington, D.C. and Delaware, the efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2012 (IECC 2012), Table C403.2.3(7). For Maryland, the efficient condition is a high-efficiency electric water chilling package exceeding the requirements presented in the International Energy Conservation Code 2015 (IECC 2015), Table C403.2.3(7).

### Annual Energy Savings Algorithm

Time of Sale and New Construction:

$$\Delta kWh = TONS * (IPLVbase - IPLVee) * EFLH.$$

Early Replacement[654]:

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

$$= TONS * (IPLVexist - IPLVee) * EFLH_{cool}.$$

---

[654] The two equations are provided to show how savings are determined during the initial phase of the measure (i.e., efficient unit relative to existing equipment) and the remaining phase (i.e., efficient unit relative to new baseline unit). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a "number of years to adjustment" and "savings adjustment" input which would be the (new baseline to efficient savings)/(existing to efficient savings). The remaining measure life should be determined on a site-specific basis.

$\Delta$kWh for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= TONS * (IPLVbase - IPLVee) * EFLH_{cool}.$$

*Where:*

*TONS* = *Total installed capacity of the water chilling package[tons].*
= *Actual Installed.*

*IPLVexist* = *Integrated Part Load Value (IPLV)*[655] *of the existing equipment [kW/ton].*

*IPLVbase* = *Integrated Part Load Value (IPLV) of the new baseline equipment [kW/ton].*
= *Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below.*[656]

*IPLVee* = *Integrated Part Load Value (IPLV) of the efficient equipment [kW/ton].*
= *Actual Installed.*

$EFLH_{cool}$ =*Full load hours for cooling equipment.*
=*If actual full load cooling hours are unknown, see table "Full Load Cooling Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load cooling hours information.*

**Summer Coincident Peak kW Savings Algorithm**

Time of Sale and New Construction:

$$\Delta kW = TONS * (Full\_Loadbase - Full\_Loadee) * CF.$$

Early replacement:

$\Delta$kW for remaining life of existing unit (i.e., measure life less the age of the existing equipment):

$$= TONS * (Full\_Loadexist - Full\_Loadee) * CF.$$

$\Delta$kW for remaining measure life (i.e., measure life less the remaining life of existing unit):

$$= TONS * (Full\_Loadbase - Full\_Loadee) * CF.$$

*Where:*

*Full_Loadexist = Full load efficiency of the existing equipment [kW/ton].*
*Full_Loadbase = Full load efficiency of the baseline equipment [kW/ton].*

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[655] Integrated Part Load Value (IPLV) is an HVAC industry standard single-number metric for reporting part-load performance.

[656] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages and International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Packages - Efficiency Requirements

= *Varies by equipment type and capacity. See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below*[657]

*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.*[658]

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

= *0.923.*[659]

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 23 years[660].

### Reference Tables

**Time of Sale Baseline Equipment Efficiency for Washington, D.C. and Delaware**[661]

| 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 | <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 |

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[657] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages and International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Packages - Efficiency Requirements

[658] 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.

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

[660] 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"

[661] Baseline efficiencies based on International Energy Conservation Code 2012, Table C403.2.3(7) Minimum Efficiency Requirements: Water Chilling Packages.

| Equipment Type | Size Category | Units | Path A[a] | | Path B[a] | |
|---|---|---|---|---|---|---|
| | | | Full Load | IPLV | Full Load | IPLV |
| Operated, Centrifugal | ≥600 tons | kW/ton | ≤0.570 | ≤0.539 | ≤0.590 | ≤0.400 |

a. Compliance with IECC 2012 can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.

### Time of Sale Baseline Equipment Efficiency for Maryland[662]

| Equipment Type | Size Category | Units | Path A[a] | | Path B[a] | |
|---|---|---|---|---|---|---|
| | | | Full Load | IPLV | Full Load | IPLV |
| Air-Cooled Chillers | <150 tons | EER | ≥10.100 | ≥13.700 | ≥9.700 | ≥15.800 |
| | ≥150 tons | EER | ≥10.100 | ≥14.000 | ≥9.700 | ≥16.100 |
| Water Cooled, Electrically Operated, Positive Displacement | <75 tons | kW/ton | ≤0.750 | ≤0.600 | ≤0.780 | ≤0.500 |
| | ≥75 tons and <150 tons | kW/ton | ≤0.720 | ≤0.560 | ≤0.750 | ≤0.490 |
| | ≥150 tons and <300 tons | kW/ton | ≤0.660 | ≤0.540 | ≤0.680 | ≤0.440 |
| | ≥300 tons and <600 tons | kW/ton | ≤0.610 | ≤0.520 | ≤0.625 | ≤0.410 |
| | ≥600 tons | kW/ton | ≤0.560 | ≤0.500 | ≤0.585 | ≤0.380 |
| Water Cooled, Electrically Operated, Centrifugal | <150 tons | kW/ton | ≤0.610 | ≤0.550 | ≤0.695 | ≤0.440 |
| | ≥150 tons and <300 tons | kW/ton | ≤0.610 | ≤0.550 | ≤0.635 | ≤0.400 |
| | ≥300 tons and <400 tons | kW/ton | ≤0.560 | ≤0.520 | ≤0.595 | ≤0.390 |
| | ≥400 tons and <600 tons | kW/ton | ≤0.560 | ≤0.500 | ≤0.585 | ≤0.380 |
| | ≥600 tons | kW/ton | ≤0.560 | ≤0.500 | ≤0.585 | ≤0.380 |

a. Compliance with IECC 2015 can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B.

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[662] Baseline efficiencies based on International Energy Conservation Code 2015, Table C403.2.3(7) Water Chilling Package - Efficiency Requirements.

# Commercial Gas Boiler

**0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to high efficiency gas boilers installed in place of standard efficiency gas boilers in commercial and industrial facilities. There are two separate criteria based on the Btu/h rating of the boiler:

1) <300,000 Btu/h follow residential measure guidelines
2) $\geq$300,000 Btu/h follow commercial measure guidelines

This measure applies to time of sale and new construction opportunities

### Definition of Baseline Condition

The baseline condition is a gas boiler with efficiency equal to the current federal standards. See the “Equipment Efficiency” table in the “Reference Tables” section.

### Definition of Efficient Condition

The efficient condition is a gas boiler that meets Energy Star criteria. See the “Equipment Efficiency” table in the “Reference Tables” section.

### Annual Energy Savings Algorithm

n/a

### Summer Coincident Peak kW Savings Algorithm

n/a

### Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = CAP * EFLH_{GAS} * (1/EFF_{base} - 1/EFF_{ee}) / 1,000,000$$

*Where:*

*CAP = Equipment output capacity [BTU/h]*
*= Actual Installed*

$EFLH_{GAS}$ *= Full Load Heating Hours*
*= See “Full Load Heating Hours by Location and Building Type” Appendix F*

$EFF_{base}$ *= 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*
*= See “Baseline Equipment Efficiency” table in the “Reference Tables” section below.*

$EFF_{ee}$ *= 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

**Measure Life**

The measure life is assumed to be 20 years[663].

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[663] Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

## Reference Tables

### Equipment Efficiency

**Gas Boiler Equipment Efficiency**

| Equipment Type | Size Category | Subcategory or Rating Condition | Baseline Efficiency[664] [665] | Efficient Criteria[666] |
|---|---|---|---|---|
| Boilers, Gas-fired | <300,000 BTU/h[667] | Hot water | 82% AFUE | 90% AFUE |
| | | Steam | 80% AFUE | 90% AFUE |
| | >=300,000 BTU/h and <=2,500,000 BTU/h | Hot water | 80% $E_t$ | ≥94% $E_t$<br>5:1 turndown |
| | | Steam – all, except natural draft | 79.0% $E_t$ | ≥94% $E_t$<br>5:1 turndown |
| | | Steam – natural draft | 77.0% $E_t$ | ≥94% $E_t$<br>5:1 turndown |
| | >2,500,000 BTU/h | Hot water | 82.0% $E_c$ | ≥94% $E_t$<br>5:1 turndown |
| | | Steam – all, except natural draft | 79.0% $E_t$ | ≥94% $E_t$<br>5:1 turndown |
| | | Steam – natural draft | 77.0% $E_t$ | ≥94% $E_t$<br>5:1 turndown |

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[664] For commercial standards Title 10 → Chapter II → Subchapter D → Part 431 → Subpart E

[665] https://up.codes/viewer/pennsylvania/iecc-2015/chapter/CE_4/ce-commercial-energy-efficiency#CE_4

[666] Energy Star Commercial boiler requirements

[667] Reference residential measure in this manual and Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32

# Commercial Gas Furnace <255,000 BTU/h

**Unique Measure Code: CI_HV_TOS_GASFUR_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to a high efficiency gas furnace with capacity less than 225,000 BTU/h, and installed in place of a standard efficiency gas furnace in a commercial or industrial facility. Note that this equipment falls into the residential category with residential standards, while the measure reflects this type and capacity of equipment being installed in a commercial application. This measure applies to time of sale and new construction opportunities.

### Definition of Baseline Condition

**Time of Sale**: The baseline condition is a minimum federal efficiency code standard gas furnace with an Annual Fuel Utilization Efficiency (AFUE) of 80%[668] with a high efficiency furnace fan.[669]

### Definition of Efficient Condition

The efficient condition is an ENERGY STAR qualified gas-fired furnace with an AFUE rating ≥ 90%. This characterization only applies to furnaces with capacities less than 225,000 BTU/h.

### Annual Energy Savings Algorithm

NA

### Summer Coincident Peak kW Savings Algorithm

NA

### Annual Fossil Fuel Savings Algorithm

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

*Where:*

$EFLH_{GAS}$ = *Full Load Heating Hours*
*See Appendix F "Full Load Heating Hours by Location and Building Type"*

$AFUE_{base}$ = *Annual Fuel Utilization Efficiency of the baseline equipment.*
= *For time of sale: 0.80.*[670]

$AFUE_{ee}$ = *Annual Fuel Utilization Efficiency of the efficient equipment.*
= *Actual Installed.*

*1,000,000* = *BTU/MMBTU unit conversion factor.*

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[668] ECFR Title 10 → Chapter II → Subchapter D → Part 431→ Subpart D

[669] Efficient furnace fan motor required as baseline, 7/3/2019

[670] ECFR Title 10 → Chapter II → Subchapter D → Part 431→ Subpart D

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 18 years[671].

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[671] 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"

# Commercial Gas Furnace ≥225,000 BTU/h

**Unique Measure Code: CI_HV_TOS_GASFURN_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure applies to the installation of a high efficiency gas furnace with an input capacity greater than or equal to 225,000 BTU/h, in place of a standard efficiency gas furnace. This measure applies to time of sale opportunities in the C&I market used in non-residential or multi-family residential installation.

A commercial warm air furnace means a self-contained oil-fired or gas-fired furnace, $\geq$225,000 BTU/hr, designed to supply heated air through ducts to spaces that require it and includes combination warm air furnace/electric air conditioning units but does not include unit heaters and duct furnaces.[672]

### Definition of Baseline Condition

The baseline condition is a gas furnace with a Thermal Efficiency (TE) of 80%[673].

### Definition of Efficient Condition

The efficient condition is a gas furnace with a TE of $\geq$90%.[674]

### Annual Electric Energy Savings Algorithm

NA

### Summer Coincident Peak kW Savings Algorithm

NA

### Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = CAP * EFLH_{GAS} * (1/TE_{Base} - 1/TE_{Eff}) / 1{,}000{,}000$$

*Where:*

$EFLH_{GAS}$ = *See Full Load Heating Hours, Appendix F.*
= *If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information*
*CAP* = *Capacity (output) of the high-efficiency equipment [BTU/h].*
= *Actual Installed.*
$TE_{base}$ = *Thermal Efficiency of the baseline equipment.*
= *0.80*
$TE_{ee}$ = *Thermal Efficiency of the efficient equipment.*

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[672] CFR Title 10 → Chapter II → Subchapter D → §431.71
[673] CFR Title 10 → Chapter II → Subchapter D → §431.77
[674] As agreed by 2019 TRM team via conference call. There is no published specification for high efficiency gas furnace >225kBtu

= *Actual Installed.*

*1,000,000* = *BTU/MMBTU unit conversion factor.*

**Example Calculation** for MMBtu reduction of a 90%TE 400,000 Btu furnace in a sit-down restaurant in Dover DE:

Annual Gas MMBtu savings

$\Delta$MMBTU = 400,000 * 1,131 * (1/.80 – 1/.90) / 1,000,000

= 62.8 MMBtu

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 23 years[675].

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[675] EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018 (prepared by Navigant Consulting, Inc.)

# Dual Enthalpy Economizer

**Unique Measure Code: CI_HV_RF_DEECON_0614**
**Effective Date: June 2014**
**End Date: TBD**

### Measure Description

This measure involves the installation of a dual enthalpy economizer to provide free cooling during the appropriate ambient conditions. Enthalpy refers to the total heat content of the air. A dual enthalpy economizer uses two sensors — one measuring return air enthalpy and one measuring outdoor air enthalpy. Dampers are modulated for optimum and lowest enthalpy to be used for cooling. This measure applies only to retrofits.

### Definition of Baseline Condition

The baseline condition is the existing HVAC system with no economizer.

### Definition of Efficient Condition

The efficient condition is the HVAC system with dual enthalpy controlled economizer.

### Annual Energy Savings Algorithm

$$\Delta kWh = TONS * SF$$

*Where:*

*TONS = Actual Installed.*
*SF = Savings factor for the installation of dual enthalpy economizer control [kWh/ton].*
*= See "Savings Factors" table in "Reference Tables" section below.*[676]

### Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = 0 \text{ kW}.$$[677]

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 10 years[678].

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[676] 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.

[677] Demand savings are assumed to be zero because economizer will typically not be operating during the peak period.

[678] General agreement among sources; Recommended value from Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009.

## Reference Tables

**Savings Factors**[679]

| Savings Factors (kWh/ton) | Dover, DE | Wilmington, DE | Baltimore, MD | Hagerstown, MD | Patuxent River, MD | Salisbury, MD | Washington D.C. |
|---|---|---|---|---|---|---|---|
| Assembly | 26 | 22 | 25 | 29 | 25 | 27 | 25 |
| Big Box Retail | 58 | 50 | 57 | 66 | 57 | 62 | 56 |
| Fast Food | 37 | 32 | 37 | 42 | 36 | 40 | 36 |
| Full Service Restaurant | 29 | 25 | 29 | 34 | 29 | 32 | 28 |
| Light Industrial | 24 | 21 | 23 | 27 | 23 | 25 | 23 |
| Primary School | 40 | 34 | 39 | 45 | 39 | 43 | 39 |
| Small Office | 58 | 50 | 57 | 66 | 57 | 62 | 56 |
| Small Retail | 58 | 50 | 57 | 66 | 57 | 62 | 56 |
| Religious | 6 | 5 | 6 | 6 | 6 | 6 | 6 |
| Warehouse | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Other | 58 | 50 | 57 | 66 | 57 | 62 | 56 |

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[679] kWh/ton savings from NY Standard Approach Model, with scaling factors based on enthalpy data from NYC and Mid-Atlantic cities. Note: Values for Big Box Retail, Small Office, and Small Retail are anomalously high and have been set equal to the “Other” building type for conservatism based on discussion with the Mid-Atlantic TRM Stakeholder Group.

# AC Tune-Up

## Unique Measure Code(s): CI_HV_RF_ACTUNE_0420
## Effective Date: April 2020
## End Date: TBD

### Measure Description

This measure is for a "tune-up" for a commercial central AC. This measure only applies to residential-style central AC systems of 5.4 tons (65,000 BTU/h) or less. Tune-ups for larger units, including units with variable air volume and air handling units, should be treated as custom measures. A recent California evaluation suggests that tune-ups on these larger systems may be better handled by breaking up the overall tune-up into a series of specific activities performed – for example, refrigerant charge correction, economizer repair, leak sealing, etc.[680] For smaller units, tuning measures may include:

- Refrigerant charge correction
- Air flow adjustments
- Cleaning the condensate drain line
- Clean and straighten coils and fans
- Replace air filter
- Repair damaged insulation

### Definition of Baseline Condition

The baseline condition is a pre-tune-up air conditioner. Where possible, spot measurements should be used to estimate the baseline EER. An HVAC system is eligible for a tune-up once every five years.

### Definition of Efficient Condition

The efficient condition is a post-tune-up air conditioner. Where possible, spot measurements should be used to estimate the EER post-tune-up.

### Annual Energy Savings Algorithm

$$\Delta kWh = CCAP \times EFLH \times 1/SEER_{pre} \times \%\_impr.$$

*Where:*

*CCAP* = *Cooling capacity of existing AC unit, in kBTU/hr.*

$SEER_{pre}$ = *SEER of actual unit, before the tune-up. If testing is not done on the baseline condition, use the nameplate SEER.*

*EFLH* = *Full load hours for cooling equipment.*
= *If actual full load cooling hours are unknown, see table "Full Load Cooling Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load cooling hours information.*

*%_impr* = *Percent improvement based on measured EERs pre- and post-tune-up. Calculated as* $(EER_{post} – EER_{pre})/EER_{post}$*, where subscripts "pre" and*

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[680] California Public Utilities Commission. *HVAC Impact Evaluation Final Report.* January 28, 2014.

*"post" refer to the EER before and after the tune-up, respectively. If onsite testing data is not available, assume %_impr = 0.05.*[681]

## Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = CCAP \times 1/EER_{pre} \times \%\_impr \times CF.$$

*Where:*

$CCAP$ = *Cooling capacity of DMSHP unit, in kBTU/hr.*

$EER_{pre}$ = *EER of actual unit, before the tune-up. If testing is not done on the baseline condition, use the nameplate EER.*

$\%\_impr$ = *Percent improvement based on measured EERs pre and post tune-up. Calculated as* $(EER_{post} – EER_{pre})/EER_{post}$. *If onsite testing data is not available, assumed %_impr = 0.05.*[682]

$CF_{PJM}$ = *PJM Summer Peak Coincidence Factor (June to August weekdays between 2 pm and 6 pm) valued at peak weather.*
= *0.360 for units <135 kBTU/h and 0.567 for units ≥135 kBTU/h.*[683]

$CF_{SSP}$ = *Summer System Peak Coincidence Factor (hour ending 5pm on hottest summer weekday)*
= *0.588 for units <135 kBTU/h and 0.874 for units ≥135 kBTU/h.*[684]

## Annual Fossil Fuel Savings Algorithm

n/a

## Measure Life

The measure life for an AC tune-up is 5 years.[685]

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[681] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

[682] Energy Center of Wisconsin, May 2008; "Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research."

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

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

685 GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

# Smart Thermostat*

**Unique Measure Code(s): CI_ HV_TOS_SMTHRM_0420 CI_ HV_RF_SMTHRM_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

The Smart Thermostat measure involves the replacement of a manually operated or conventional programmable thermostat with a "smart" thermostat (defined below). This measure only applies to thermostats that control central A/C, heat pump, furnace, or rooftop units (RTUs) with capacity up to 300,000 BTU/h) that serve normal conditioned spaces, not semi-conditioned spaces or spaces with large frequently open doors (e.g. loading docks and car repair shops). Thermostats for larger systems should be treated as custom measures. This measure may be a time of sale, retrofit, or new construction measure.

### Definition of Baseline Condition

**Retrofit:** As a retrofit measure, the baseline equipment is the in-situ manually operated or properly programmed thermostat that was replaced. If a manually operated non-programmable thermostat baseline is claimed, supporting photographic documentation should be collected.

**Time of Sale or New Construction:** The baseline condition is a programmable thermostat meeting minimum efficiency standards as presented in the 2012 International Energy Conservation Code (IECC 2012) and the 2015 International Energy Conservation Code (IECC 2015).

### Definition of Efficient Condition

The efficient condition is a smart thermostat that has earned ENERGY STAR certification[686] or has the following product requirements[687]:

1. Automatic scheduling
2. Occupancy sensing (set "on" as a default)
3. For homes with a heat pump, smart thermostats must be capable of controlling heat pumps to optimize energy use and minimize the use of backup electric resistance heat.
4. Ability to adjust settings remotely via a smart phone or online the absence of connectivity to the connected thermostat (CT) service provider, retain the ability for residents to locally:
    a. view the room temperature,
    b. view and adjust the set temperature, and
    c. switch between off, heating and cooling.
5. Have a static temperature accuracy ≤ ± 2.0 °F
6. Have network standby average power consumption of ≤ 3.0 W average (Includes all equipment necessary to establish connectivity to the CT service provider's cloud, except

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[686] ENERGY STAR's qualified products list for smart thermostats: https://data.energystar.gov/dataset/ENERGY-STAR-Certified-Connected-Thermostats/7p2p-wkbf

[687] ENERGY STAR Smart Thermostat Specification, from which most requirements based: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0_0.pdf

those that can reasonably be expected to be present in the home, such as Wi-Fi routers and smart phones.)

7. Enter network standby after ≤ 5.0 minutes from user interaction (on device, remote or occupancy detection)
8. The following capabilities may be enabled through the CT device, CT service or any combination of the two. The CT product shall maintain these capabilities through subsequent firmware and software changes.
    a. Ability for consumers to set and modify a schedule.
    b. Provision of feedback to occupants about the energy impact of their choice of settings.
    c. Ability for consumers to access information relevant to their HVAC energy consumption, e.g. HVAC run time.

**Annual Energy Savings Algorithm**

As smart thermostats are control technologies, when possible, heating and cooling savings should be calculated based on data from installed thermostats.[688] Otherwise, cooling savings should only be claimed for buildings with central air conditioning. Heating savings may be claimed for buildings with electric resistance, heat pump, or non-electric heating.

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

$\Delta kWh_{cooling} = CCAP \times EFLH_{cool} \times 1/SEER \times ElecCool\_Saving\_\%$

$\Delta kWh_{heating} = HCAP_{elec} \times EFLH_{heat} \times 1/HSPF \times ElecHeat\_Saving\_\%$

$\Delta MMBTU = HCAP_{fuel} \times EFLH_{heat} \times 1/AFUE \times FuelHeat\_Saving\_\%$

*Where:*

*CCAP = Cooling capacity of existing AC unit, in kBTU/hr.*

*$EFLH_{cool}$ = Full load hours for cooling equipment. See table "Full Load Cooling Hours by Location and Building Type" in Appendix F.*

*SEER = SEER of controlled unit. If unknown use current energy code requirements for mechanical cooling efficiency.*

*ElecCool_Saving_% = Electrical cooling percent savings from thermostat relative to baseline control. If baseline thermostat type is known, see table "Savings Factors for Smart Thermostats by Baseline Technology" below. If baseline thermostat type is unknown, ElecCool_Savings_% = 3%.*

*$HCAP_{elec}$ = Heating capacity of existing heat pump or electric resistance unit, in kBTU/hr.*

*$EFLH_{heat}$ = Full load hours for heating equipment. See table "Full Load Heating Hours by Location and Building Type" in Appendix F.*

*HSPF = HSPF of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency.*

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[688] NEEP has developed a Guidance Document detailing methodology to claim savings from smart thermostats, available here: http://www.neep.org/claiming-savings-smart-thermostats-guidance-document. This guidance uses the metric developed for the ENERGY STAR certification to develop geographically and temporally specific savings averages for program claims. These calculated savings numbers are expected to be more accurate and potentially yield higher level of savings than the estimates provided in the TRM.

*ElecHeat_Saving_%* = *Electrical heating percent savings from thermostat relative to baseline control. If baseline thermostat type is known, see table "Savings Factors for Smart Thermostats by Baseline Technology" below. If baseline thermostat type is unknown, ElecHeat_Savings_% = 2%.*

$HCAP_{fuel}$ = *Heating capacity of existing furnace unit, in MMBTU/hr.*

*AFUE* = *AFUE of controlled unit. If unknown use current energy code requirements for mechanical heating efficiency.*

*FuelHeat_Saving_%* = *Heating fuel percent savings from thermostat relative to baseline control. If baseline thermostat type is known, see table "Savings Factors for Smart Thermostats by Baseline Technology" below. If baseline thermostat type is unknown, FuelHeat_Savings_% = 2%.*

**Savings Factors for Smart Thermostats by Baseline Technology**

| | Baseline Technology | |
|---|---|---|
| Fuel and Function | Manual Thermostat[689] | Programmable Thermostat[690] |
| Savings factor for electric cooling, *ElecCool_Saving_%* | 5% | 3% |
| Savings factor for electric heating, *ElecHeat_Saving_%* | 4% | 2% |
| Savings factor for fuel heating, *FuelHeat_Saving_%* | 5% | 2% |

## Summer Coincident Peak kW Savings Algorithm

The smart thermostat measure as defined here (i.e., without a corresponding demand reduction program) is assumed to have no demand savings. Smart thermostats with a demand response program added on top may generate significant demand savings, but those are not quantified as part of this measure.

## Annual Water Savings Algorithm

n/a

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[689] The savings percentages claimed for manual thermostats include the savings associated with upgrading from manual thermostats to programmable thermostats, which a 2015 MEMD study reported as about 3% savings for gas customers and 2% savings for electric customers. http://www.michigan.gov/documents/mpsc/CI_Programmable_TStats_MEMD_6_15_15_491808_7.pdf

[690] Relative to a programmable thermostat, smart thermostats have savings opportunities available from a "smart recovery" function, which enables users to set the time they would like the building to reach a temperature as opposed to setting a time that the unit should start operating. Savings are also available from improved error detection and from locking out building occupants' ability to override programmed schedules. Individual case studies have demonstrated savings in a variety of small commercial applications, but large-scale evaluations of smart thermostat savings have so far been limited to thermostats installed in residential applications. CLEAResult's "Guide to Smart Thermostats" reports the ranges of savings measured in recent *residential* evaluations, relative to a baseline that blended programmable and manual thermostats: 10–13% for gas savings; 14–18% for electric cooling savings; and 6–13% for electric heating savings. https://www.clearesult.com/insights/whitepapers/guide-to-smart-thermostats/

**Measure Life**

The measure life is assumed to be 7.5 years.[691]

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[691] Based on professional judgment of TRM technical team. EULs observed for residential applications include: 11 years in AR TRM and 10 years in IL TRM, both of which are based on programmable thermostat EULs. CA workpapers conclude 3-year EUL using persistence modeling. RTF concludes a 5-year EUL based on CA workpapers and concerns that there is little basis for assuming long-time persistence of savings, considering past challenges with manual overrides and "know-how" needed to use wifi-connected devices, including communicating hardware and software downloading. For discussion, see Northwest Regional Technical Forum April 2017. https://nwcouncil.box.com/v/ResConnectedTstatsv1-2

# Variable Refrigerant Flow (VRF) Heat Pump Systems

**Unique Measure Code(s): CI_HV_TOS_VRFHP_0420, CI_HV_EREP_VRFHP_0619, CI_HV_NC_VRFHP_0420**
**Effective Date: April 2020**
**End Date: TBD**

## Measure Description

This measure relates to the installation of new high efficiency variable refrigerant flow (VRF) heat pump(s) also known as variable refrigerant volume (VRV). A VRF system is a type of heat pump with one outdoor condensing unit circulating refrigerant to multiple indoor evaporator units. A DC inverter in the compressor allows for variable motor speed which in turn provides variable refrigerant flow. VRF systems deliver cooling and heating at higher efficiency than traditional air-source heat pumps. Because the energy transported to and from zones is through piped refrigerant and not ductwork, VRF avoid ductwork transport losses to and from zones. Some units can provide heating and cooling to different zones simultaneously, using waste heat from cooling one or more zones to heat others when possible. This measure does not include that heat recovery capability, though installations achieving additional savings through heat recovery are encouraged to claim savings through custom site-specific means.

## Definition of Baseline Condition

**Time of Sale or New Construction[692]:** For New Construction, the baseline will be a minimally compliant VRF system. For Time of Sale, the baseline will depend on if there is a pre-existing HVAC system. If there is a pre-existing system, the baseline will be a system of the same type with code minimum efficiency. If there is no pre-existing cooling system or the system is unknown, then the baseline system will be a minimally compliant VRF system. Minimally compliant is determined by the local energy code or federal efficiency standards, whichever has the higher efficiency.

**Early Replacement:** The baseline condition for the Early Replacement measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit, and the new baseline will be a system of the same type with code minimum efficiency for the remainder of the measure life.[693] If the space is currently uncooled and the VRF adds cooling capability, the project will be considered new construction, with a new construction baseline.

In the event of fuel-switching, e.g. switching away from or displacing an existing system including gas heat, the VRF constitutes a new application and a code minimum VRF should be the assumed baseline. Air source heat pumps or electric resistance heat should only be used as the baseline when that is the existing system being replaced in a retrofit or early retirement scenario.

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[692] In new construction, since VRF systems are “ductless” the baseline should also be ductless, which is why a VRF system is chosen for the baseline.

[693] To enable improvements to this measure characterization in the future, the existing equipment types should be tracked by the program to ensure that this measure characterizes the appropriate baseline conditions.

### Definition of Efficient Condition

The efficient equipment is a high-efficiency VRF system meeting or exceeding CEE Tier 1 efficiency levels. Savings will be calculated using actual equipment specifications.

### Baseline and Efficient Levels by Unit Capacity

If the measure is an early replacement, the actual efficiencies of the baseline heating and cooling equipment should be used. If it is a time of sale, the baseline efficiency should be selected from the tables below.

**System Efficiency**

| Equipment Type | Capacity (Btu/h) | Code Minimum[694] | Minimum Qualifying Efficiency[695] |
|---|---|---|---|
| VRF – air cooled (cooling mode) | < 65,000 Btu/h | 13.0 SEER<br>11.2 EER | 15.0 SEER<br>12.5 EER |
| | 65,000 ≤ Btu/h < 135,000 | 12.3 IEER<br>11.0 EER | 14.2 IEER<br>11.3 EER |
| | 135,000 ≤ Btu/h < 240,000 | 11.8 IEER<br>10.6 EER | 13.7 IEER<br>10.9 EER |
| | ≥ 240,000 Btu/h | 10.6 IEER<br>9.5 EER | 12.5 IEER<br>10.3 EER |
| VRF – air cooled (heating mode) | < 65,000 Btu/h (cooling capacity) | 7.7 HSPF | 8.5 HSPF |
| | 65,000 ≤ Btu/h < 135,000 (cooling capacity) | 47°F db / 43°F wb outdoor Air 3.3 $COP_H$ | 3.4 COP |
| | | 17°F db / 15°F wb outdoor Air 2.25 $COP_H$ | 2.4 COP |
| | ≥ 135,000 Btu/h (cooling capacity) | 47°F db / 43°F wb outdoor Air 3.2 $COP_H$ | 3.2 COP |
| | | 17°F db / 15°F wb outdoor Air 2.05 $COP_H$ | 2.1 COP |
| VRF – water cooled (cooling mode) | < 65,000 Btu/h (cooling capacity) | 12.0 EER | 14.0 EER |
| | 65,000 ≤ Btu/h < 135,000 | 12.0 EER | 14.0 EER |

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[694] ASHRAE 90.1 2013, Table 6.8.1-10.

[695] CEE Tier 1 efficiencies. https://library.cee1.org/system/files/library/7559/Appendix_A_2016-18_CEE_ComACHP_UnitarySpec.pdf

| Equipment Type | Capacity (Btu/h) | Code Minimum[694] | Minimum Qualifying Efficiency[695] |
|---|---|---|---|
| | (cooling capacity) | | |
| | ≥ 135,000 Btu/h (cooling capacity) | 10.0 EER | 12.0 EER |
| VRF – water cooled (heating mode) | < 135,000 Btu/h (cooling capacity) | 4.2 $COP_H$ | 4.6 COP |
| | ≥ 135,000 Btu/h (cooling capacity) | 3.9 $COP_H$ | 4.3 EER |

**Annual Energy Savings Algorithm**

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

$\Delta kWh_{cool} = (BTU/h_{cool}/1000) * (1/CEF_{base} – 1/CEF_{ee}) * EFLH_{cool}.$

$\Delta kWh_{heat}$ [696] $= (ELECHEAT * BTU/h_{heat} /HEF_{base} – BTU/h_{heat} /HEF_{ee}) / HU * EFLH_{heat}.$

*Where:*

*$BTU/h_{cool}$ = Cooling capacity of VRF system, in BTU/hr.*

*1000 = Btu/hr to kBTU/hr conversion factor*

*$CEF_{base}$ = Baseline Cooling Efficiency Factor. SEER if $BTU/h_{cool} < 65,000$ Btu/hr. IEER if $BTU/h_{cool} \geq 65,000$ Btu/hr.*

- *If early replacement, $CEF_{base}$ will be the efficiency of the existing unit for the Remaining Useful Life (RUL). At the end of its RUL, $CEF_{base}$ becomes code minimum. New Construction and Time of Sale always use code minimum.*
- *If early replacement and prior unit's SEER or IEER is unavailable, use EER for savings calculations. If EER is also unavailable, use code minimum SEER or IEER as appropriate.*

*$CEF_{ee}$ = Cooling Efficiency Factor of installed VRF system. SEER if $BTU/h_{cool} < 65,000$ Btu/hr. IEER if $BTU/h_{cool} \geq 65,000$ Btu/hr.*

- *If early replacement and baseline SEER or IEER is unavailable, and baseline EER is used, use efficient EER as well.*

*$EFLH_{cool}$ = Full load hours for cooling equipment.*

*= If actual full load cooling hours are unknown, see table "Full Load Cooling Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load cooling hours information.*

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[696] This will be negative if the baseline has non-electric heat. This is because some electricity from the VRF system is now assumed to be used for space heating. There is a corresponding savings in fossil fuel heat.

*$BTU/h_{heat}$ = Heating capacity of VRF unit, in BTU/hr.*
*ELECHEAT = 1 if the baseline heating fuel is electric. 0 if fossil fuel.*
*$HEF_{base}$ = Heating Efficiency Factor of baseline equipment. HSPF if $BTU/h_{cool} < 65{,}000$ BTU/hr. $COP_H$ if $BTU/h_{cool} \geq 65{,}000$ BTU/hr. See table above.*
*If early replacement, $HEF_{base}$ will be the efficiency of the existing unit for the remainder of its useful life (RUL). At the end of its RUL, $HEF_{base}$ becomes code minimum. New Construction and Time of Sale always use code minimum.*
*$HEF_{ee}$ = Heating Efficiency Factor of actual VRF system. HSPF if $BTU/h_{cool} < 65{,}000$ BTU/hr. $COP_H$ if $BTU/h_{cool} \geq 65{,}000$ BTU/hr. See table above.*
*HU = Heating Units factor. If HEF are in HSPF, HU = 1000 (BTU/kBTU). If HEF are in COP, HU = 3412 (BTU/kWh).*
*$EFLH_{heat}$ = Full load hours for heating equipment.*
*= If actual full load heating hours are unknown, see table “Full Load Heating Hours by Location and Building Type” in Appendix F. Otherwise, use site specific full load heating hours information*

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = BTU/h_{cool} / 1000 * (1/EER_{base} - 1/EER_{ee}) * CF.$$

*Where:*

*$EER_{base}$ = EER of baseline unit.*
- *If early replacement, $EER_{base}$ will be the efficiency of the existing unit for its Remaining Useful Life (RUL). At the end of its RUL, $EER_{base}$ becomes code minimum. New Construction and Time of Sale always use code minimum.*

*$EER_{ee}$ = EER of installed VRF system.*
*$CF_{PJM}$ = PJM Summer Peak Coincidence Factor valued at peak weather.*
*= 0.360 for units <135 kBtu/h and 0.567 for units ≥135 kBtu/h.*[697]
*$CF_{SSP}$ = Summer System Peak Coincidence Factor*
*= 0.588 for units <135 kBtu/h and 0.874 for units ≥135 kBtu/h.*[698]

**Annual Fossil Fuel Savings Algorithm**

Note: Only applies if retrofit space is heated with fossil fuels. Negative value denotes *increased* fossil fuel consumption.

$$\Delta MMBtu = BTU/h_{heat} \times EFLH_{heat} / TE / 1{,}000{,}000$$

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

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

*Where:*

*$EFLH_{heat}$ = Full load hours for heating equipment. See table above.*

*TE = Thermal Efficiency of baseline equipment. If unknown use 80% for units with a heating capacity $\leq$2,500 kBtu/h and 82% for units with a heating capacity >2,500 kBtu/h.*[699]

**Measure Life**

The measure life is assumed to be 15 years.[700]

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[699] Federal standard for gas-fired hot water boilers, based on ASHRAE 90.1 2007, table 6.8.1F, matched by IECC 2015, table C403.2.3(5).

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

# Steam Boiler Traps – Repair/Replace

**Unique Measure Code(s): CI_HV_TOS_TRAP_0619**
**Effective Date: June, 2019**
**End Date: TBD**

## Measure Description

This measure describes the replacement or repair of a medium to high pressure process boiler's steam traps where at least one steam trap is not functioning properly and needs to be repaired. Often, traps fail open, meaning that heat escapes constantly during normal operation, thus wasting much available energy. This measure involves fixing or replacing broken traps to ensure proper operation.

## Definition of Baseline Condition

To qualify for this measure, customers must have leaking or failed closed steam traps. This measure is intended only to replace traps that are not functioning properly. There is no minimum leak rate.

## Definition of Efficient Condition

A boiler with all steam traps functioning properly.

## Annual Energy Savings Algorithm

n/a

## Summer Coincident Peak kW Savings Algorithm

n/a

## Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (SteamTrapDischargeRate * HOURS * h_{fg}) / (\eta Boiler * 1{,}000{,}000)$$

$$SteamTrapDischargeRate = 24.24^{701} * Dia^2 * P_a * 50\%$$

$$P_a = psig + psia$$

*Where:*

*SteamTrapDischargeRate* = Hourly rate of steam loss per trap (lb/hr).
*HOURS* = Actual operating hours/year
= If actual operating hours are unknown, use the Steam Trap Default Table below.
*$h_{fg}$* = Latent heat of vaporization (Btu/lb). See Heat of Vaporization table below.

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[701] 24.24 = Steam loss constant per Napier's equation (lb/hr-psia-in2)

*ηBoiler* = Thermal efficiency of boiler. Assume 80.7%[702] if unknown.

*Dia* = Internal diameter of steam trap orifice. Use default value from Steam Trap Default table below if unknown.

$P_a$ = Absolute steam pressure (psi)

*psig* = Steam gage pressure (psi). Use default value from Steam Trap Default table below if unknown.

*psia* = Atmospheric pressure (psi). Use standard atmospheric value, 14.7, if unknown.

*50%* = Deemed value for percent of orifice open.

**Heat of Vaporization[703]**

| Pressure (psig) | Heat of Vaporization (Btu/lb) |
|---|---|
| 16 | 944 |
| 20 | 939 |
| 30 | 929 |
| 40 | 920 |
| 50 | 912 |
| 60 | 906 |
| 75 | 895 |
| 100 | 880 |
| 125 | 868 |
| 150 | 857 |
| 175 | 847 |
| 200 | 837 |
| 225 | 828 |
| 250 | 820 |
| 275 | 812 |
| 300 | 805 |

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[702] T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993

[703] The Engineering Toolbox, Properties of Saturated Steam - Imperial Units, https://www.engineeringtoolbox.com/saturated-steam-properties-d_273.html

**Steam Trap Default Table**

| Steam System | Average Steam Trap Inlet Pressure (psig)[704] | Dia (diameter of orifice, in.) | HOURS[705] |
|---|---|---|---|
| Medium Pressure (>15 psig, <30 psig) | 16 | 0.1875 | 8,631 |
| Medium Pressure (≥30 psig, <75 psig) | 47 | 0.2500 | 8,284 |
| High Pressure (≥75 psig, <125 psig) | 101 | 0.2500 | 8,100 |
| High Pressure (≥125 psig, <175 psig) | 146 | 0.2500 | 8,346 |
| High Pressure (≥175 psig, <250 psig) | 202 | 0.2500 | 7,788 |
| High Pressure (≥250 psig, ≤300 psig) | 263 | 0.2500 | 8,746 |
| High Pressure (>300 psig) | Custom | Custom | 8,746 |

## Annual Water Savings Algorithm

n/a

## Measure Life

6 years[706]

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[704] Medium and high pressure steam trap inlet pressure based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours.

[705] Navigant analysis of Nicor Gas data from GPY1 to GPY3, "TRM Version 4.0 Steam Trap Measure Review", October 2015

[706] CA DEER – 2014 Updated EUL Records

# Boiler Reset and Cut-Out Controls

**Unique Measure Code(s): CI_HV_TOS_RESET_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

Boiler reset controls improve system efficiency by varying the boiler entering water temperature relative to heating load as a function of the outdoor air temperature. The water can be run cooler during fall and spring than during the coldest parts of the winter. Boiler cut-out controls turn off a boiler and its connected heating system when sensors determine that the outside air has reached a specified temperature. Optionally, a timer to de-energize the heating equipment may also be included.

Most often, these controls are installed together, as controls do exist which can accomplish both functions.

### Definition of Baseline Condition

Existing boiler without boiler reset or cut-out controls.

### Definition of Efficient Condition

Installation of boiler reset controls and/or boiler cut-out controls. The system must be set so that the minimum temperature is not more than 10 degrees above manufacturer's recommended minimum return temperature. Because boiler reset savings is minimal for non-condensing boilers, this measure is limited to cut-out controls on non-condensing boilers while both boiler reset and cut-out controls are applicable to condensing boilers.

### Annual Energy Savings Algorithm

n/a

### Summary Coincident Peak kW Savings Algorithm

n/a

### Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (Savings\ \%) * (EFLH_{GAS} * CAP * 1/Eff) / 1{,}000{,}000$$

*Where:*

*Savings %* = Estimated percent reduction in heating load due to controls being installed. See Savings Percentage table below.

$EFLH_{GAS}$ = *Full Load Heating Hours.*
= *If actual full load heating hours are unknown, see table "Full Load Heating Hours by Location and Building Type" in*

*Appendix F. Otherwise, use site specific full load heating hours information.*

*CAP* = Capacity of boiler (BTU/hr).

= Actual.

*Eff* = *The efficiency of the boiler; Can be expressed as thermal efficiency ($E_t$), combustion efficiency ($E_c$), or Annual Fuel Utilization Efficiency (AFUE), depending on equipment type and capacity.*

= *If unknown see "Baseline Equipment Efficiency" table in the "Reference Tables" section below*[707].

**Savings Percentage**

| | |
|---|---|
| Boiler Reset | 5.0%[708] |
| Boiler Cut-Out | 2.2%[709] |
| Boiler Reset & Cut-Out | 7.1% |

## Annual Water Savings Algorithm

n/a

## Measure Life

15 years[710]

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[707] Baseline efficiencies based on the Energy Independence and Security Act of 2007 and the International Energy Conservation Code 2009, Table 503.2.3(5) Boilers, Gas- and Oil-Fired, Minimum Efficiency Requirements.

[708] GDS Associates, Inc. (2009). Natural Gas Energy Efficiency Potential in Massachusetts. Prepared for GasNetworks, Table 6-4: Commercial Measure Characteristics; Energy Solutions Center. The savings factor of 5% matches between the Residential NY TRM measure and the Residential NEEP measure – therefore, since 5% was also used in the NY TRM for the Commercial measure, it is used here.

[709] Arkansas Technical Reference Manual, Version 7, Volume 2, page 234 and 229. The savings factors for Reset (3.8%) and Cut-Out (1.7%) were used to scale the Cut-Out savings factor proportionally to 2.2%.

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

## Reference Tables

**Baseline Equipment Efficiency**[711]

| Equipment Type | Size Category | Subcategory or Rating Condition | Minimum Efficiency | Minimum Efficiency after 3/2/2020 |
|---|---|---|---|---|
| Boilers, Gas-fired | <300,000 BTU/h | Hot water | 80% AFUE | 80% AFUE |
| | | Steam | 75% AFUE | 75% AFUE |
| | >=300,000 BTU/h and <=2,500,000 BTU/h | Hot water | 80% $E_t$ | 80% $E_t$ |
| | | Steam – all, except natural draft | 79.0% $E_t$ | 79.0% $E_t$ |
| | | Steam – natural draft | 77.0% $E_t$ | 79% $E_t$ |
| | >2,500,000 BTU/h | Hot water | 82.0% $E_c$ | 82.0% $E_c$ |
| | | Steam – all, except natural draft | 79.0% $E_t$ | 79.0% $E_t$ |
| | | Steam – natural draft | 77.0% $E_t$ | 79% $E_t$ |

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[711] Baseline efficiencies based on current federal standards (http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/74fr36312.pdf) and standards for each state, ASHRAE 90.1 and IECC 2015.

# Infrared Heaters

**Unique Measure Code(s): CI_HV_TOS_IRHEAT_0420**
**Effective Date: April 2020**
**End Date: TBD**

## Measure Description

This measure refers to the installation of gas-fired infrared heaters in new buildings or installation with the purpose of replacing existing gas-fired furnaces or unit heaters.

## Definition of Baseline Condition

The baseline for this measure is a standard natural gas-fired heater.

## Definition of Efficient Condition

The efficient condition is a gas-fired low or medium intensity infrared heater.

## Annual Energy Savings Algorithm

n/a

## Summer Coincident Peak kW Savings Algorithm

n/a

## Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = (1 - LRF) * CAP * EFLH_{GAS} / 1{,}000{,}000$$

$$LRF = HDD45 / (55°F - T_{design}) / (HDD55 / (65°F - T_{design}))$$[712]

*Where:*

*LRF* = Load Reduction Factor
*CAP* = The input capacity of the infrared heater (BTU/hr).
= Actual installed.
$EFLH_{GAS}$ = *Full Load Heating Hours.*
= *If actual full load heating hours are unknown, see table "Full Load Heating Hours by Location and Building Type" in Appendix F. Otherwise, use site specific full load heating hours information.*
*HDD45* = Heating degree-days of the climate zone, base of 45 degrees
*HDD55* = Heating degree-days of the climate zone, base of 55 degrees
$T_{design}$ = Equipment design temperature relative to local climate

## Annual Water Savings Algorithm

n/a

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[712] Minnesota TRM Version 2.2, May 2018. Page 383-386, "C/I HVAC – Infrared Heater".

**Measure Life**

12 years[713]

## Reference Tables

**HDD, $T_{design}$ and LRF values for selected cities[714]**

| | HDD45 | HDD55 | $T_{design}$ | LRF |
|---|---|---|---|---|
| **Wilmington, DE** | 840 | 1697 | 11 F | 60.75% |
| **Baltimore, MD** | 721 | 1499 | 15 F | 60.12% |
| **Washington, DC** | 560 | 1325 | 18 F | 53.69% |

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[713] Ibid.

[714] Values based on TMY3 data. T_design placed at 99% percent lowest temperature.

*Refrigeration End Use*

# ENERGY STAR Commercial Freezers

**0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency packaged commercial freezer intended for food product storage. This measure may involve the removal of an existing inefficient freezer from service, prior to failure.

### Definition of Baseline Condition

**Time of Sale or New Construction:** The baseline condition is a standard-efficiency commercial freezer meeting, but not exceeding, federal energy efficiency standards.

**Early Replacement:** The baseline condition for the Early Replacement measure is the existing commercial freezer for the remaining useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard.

### Definition of Efficient Condition

The efficient condition is a high-efficiency packaged commercial freezer meeting ENERGY STAR Version 4.0 requirements[715].

### Annual Energy Savings Algorithm

Time of Sale or New Construction:

$$\Delta kWh = (kWh_{BASEdailymax} - kWh_{EEdailymax}) * 365.$$

Early Replacement:

ΔkWh for remaining life of existing unit:

$$= (kWh_{EXISTdailymax} – kWh_{EEdailymax}) * 365$$

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

$$= (kWh_{BASEdailymax} - kWh_{EEdailymax}) * 365$$

*Where:*

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[715] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

*$kWh_{BASEdailymax}$* [716] *= See "Time of Sale Baseline Equipment Efficiency" table in the "Reference Tables" section below.*

*$kWh_{EEdailymax}$* [717] *= See "Time of Sale Energy Star Equipment Efficiency" table in the "Reference Tables" section below.*

*$kWh_{EXISTdailymax}$ = See "Existing Equipment Efficiency" table in the "Reference Tables" section below*

**Summer Coincident Peak kW Savings Algorithm**

Time of Sale:

$\Delta kW = (\Delta kWh/HOURS) \times CF.$

Early Replacement:

ΔkW for remaining life of existing unit:

$= (\Delta kWh/HOURS) \times CF.$

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

$= (\Delta kWh/HOURS) \times CF.$

*Where:*

*HOURS = Full load hours.*
*= 5858.* [718]
*CF = Summer Peak Coincidence Factor for measure.*
*= 0.77.* [719]

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 12 years.[720]

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[716] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

[717] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

[718] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[719] 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.

[720] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

**Reference Tables**

**Time of Sale Baseline Equipment Efficiency**

| **Product Class** | **Freezer Energy** ($kWh_{BASEdailymax}$) |
|---|---|
| Vertical Closed | |
| *Solid* | *VCS.SC.L* |
| All volumes | 0.22V+1.38 |
| *Transparent* | *VCT.SC.L* |
| All volumes | 0.29V+2.95 |
| Horizontal Closed | |
| *Solid* | *HCS.SC.L* |
| All volumes | *0.06V+1.12* |
| *Transparent* | *HCT.SC.L* |
| All volumes | 0.08V+1.23 |

*Where V = unit volume in cubic feet*

** DOE Equipment Class designations relevant to ENERGY STAR eligible product scope.*
*(1) Equipment family code (HCS= horizontal closed solid, HCT=horizontal closed transparent, VCS= vertical closed solid, VCT=vertical closed transparent).)*
*(2) Operating mode (SC=self-contained).)*
*(3) Rating Temperature (M=medium temperature (38 °F), L=low temperature (0 °F)).))*

**Time of Sale Energy Star Equipment Efficiency**

| **Product Class** | **Freezer Energy** ($kWh_{EEdailymax}$) |
|---|---|
| Vertical Closed | |
| *Solid* | *VCS.SC.L* |
| 0 < V < 15 | 0.21V+0.9 |
| 15 ≤ V < 30 | 0.12V+2.248 |
| 30 ≤ V < 50 | 0.285V-2.703 |
| 50 ≤ V | 0.142V+4.445 |
| *Transparent* | *VCT.SC.L* |
| 0 < V < 15 | 0.232V+2.36 |
| 15 ≤ V < 30 | |
| 30 ≤ V < 50 | |
| 50 ≤ V | |
| Horizontal Closed | |
| *Solid or Transparent* | *HCT.SC.L, HCS.SC.L* |
| All volumes | 0.057V+0.55 |

*Where V = unit volume in cubic feet*

**Existing Equipment Efficiency**

| **Product Class** | **Freezer Energy when existing unit was manufactured before 03/26/2017**[721] (kWh$_{EXISTdailymax}$) | **Freezer Energy when existing unit was manufactured after 03/27/2017** (kWh$_{EXISTdailymax}$) |
|---|---|---|
| **Vertical Closed** | | |
| *Solid* | *VCS.SC.L* | *VCS.SC.L* |
| All volumes | 0.40V+1.38 | 0.22V+1.38 |
| *Transparent* | *VCT.SC.L* | *VCT.SC.L* |
| All volumes | 0.75V+4.10 | 0.29V+2.95 |
| **Horizontal Closed** | | |
| *Solid* | *HCS.SC.L* | *HCS.SC.L* |
| All volumes | 0.40V+1.38 | *0.06V+1.12* |
| *Transparent* | *HCT.SC.L* | *HCT.SC.L* |
| All volumes | 0.75V+4.10 | 0.08V+1.23 |

*Where V = Unit volume in cubic feet*

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[721] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2010).

# ENERGY STAR Commercial Refrigerator

**Unique Measure Code(s): CI_RF_TOS_REFRIG_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency packaged commercial refrigerator intended for food product storage. This measure may involve the removal of an existing inefficient refrigerator from service, prior to failure.

### Definition of Baseline Condition

**Time of Sale or New Construction:** The baseline condition is a standard-efficiency commercial refrigerator meeting, but not exceeding, federal energy efficiency standards.

**Early Replacement:** The baseline condition for the Early Replacement measure is the existing commercial refrigerator for the remaining useful life of the unit, and then for the remainder of the measure life the baseline becomes a new replacement unit meeting the minimum federal efficiency standard.

### Definition of Efficient Condition

The efficient condition is a high-efficiency packaged commercial refrigerator meeting ENERGY STAR Version 4.0 requirements.[722]

### Annual Energy Savings Algorithm

Time of Sale or New Construction:

$$\Delta kWh = (kWhBASEdailymax - kWhEEdailymax) * 365.$$

Early Replacement:

ΔkWh for remaining life of existing unit:

$$= (kWh_{EXISTdailymax} – kWh_{EEdailymax}) * 365$$

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

$$= (kWh_{BASEdailymax} - kWh_{EEdailymax}) * 365$$

*Where:*

*$kWh_{BASEdailymax}$ [723] = See "Time of Sale Baseline Equipment Efficiency" table in the*

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[722] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

[723] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2013).

*"Reference Tables" section below.*

*$kWh_{EEdailymax}$ [724] = See "Time of Sale Energy Star Equipment Efficiency" table in the "Reference Tables" section below.*

*$kWh_{EXISTdailymax}$ = See "Existing Equipment Efficiency" table in the "Reference Tables" section below*

**Summer Coincident Peak kW Savings Algorithm**

Time of Sale:

$\Delta$kW

= ($\Delta$kWh/HOURS) * CF.

Early Replacement:

$\Delta$kW for remaining life of existing unit:

= ($\Delta$kWh/HOURS) * CF.

$\Delta$kW for remaining measure life (i.e., measure life less the remaining life of existing unit):

= ($\Delta$kWh/HOURS) * CF.

*Where:*

*HOURS = Full load hours.*
*= 5858.* [725]
*CF = Summer Peak Coincidence Factor for measure.*
*= 0.77.* [726]

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 12 years.[727]

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[724] ENERGY STAR Program Requirements Product Specification for Commercial Refrigerators and Freezers Eligibility Criteria Version 4.0, ENERGY STAR, September 2016.

[725] Efficiency Vermont Technical Reference User Manual No. 2013-82.5, August 2013; Derived from Washington Electric Coop data by West Hill Energy Consultants.

[726] 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.

[727] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

## Reference Tables

### Time of Sale Baseline Equipment Efficiency

| **Product Volume (in cubic feet)** | **Refrigerator (*kWhBASEdailymax)*** |
|---|---|
| Vertical Closed | |
| *Solid* | *VCS.SC.M** |
| All volumes | 0.05V+1.36 |
| *Transparent* | *VCT.SC.M* |
| All volumes | 0.1V+0.86 |
| Horizontal Closed | |
| *Solid* | *HCS.SC.M* |
| All volumes | *0.05V+0.91* |
| *Transparent* | *HCT.SC.M* |
| All volumes | 0.06V+0.37 |

*Where V = Unit volume in cubic feet*

** DOE Equipment Class designations relevant to ENERGY STAR eligible product scope*
*(1) Equipment family code (HCS= horizontal closed solid, HCT=horizontal closed transparent, VCS= vertical closed solid, VCT=vertical closed transparent).)*
*(2) Operating mode (SC=self-contained).)*
*(3) Rating Temperature (M=medium temperature (38 °F), L=low temperature (0 °F)).))*

### Time of Sale Energy Star Equipment Efficiency

| **Product Volume (in cubic feet)** | **Refrigerator (*kWhEEdailymax)*** |
|---|---|
| Vertical Closed | |
| *Solid* | *VCS.SC.M** |
| $0 < V < 15$ | 0.022V+0.97 |
| $15 \leq V < 30$ | 0.066V+0.31 |
| $30 \leq V < 50$ | 0.04V+1.09 |
| $50 \leq V$ | 0.024V+1.89 |
| *Transparent* | *VCT.SC.M* |
| $0 < V < 15$ | 0.095V+0.445 |
| $15 \leq V < 30$ | 0.05V+1.12 |
| $30 \leq V < 50$ | 0.076V+0.34 |
| $50 \leq V$ | 0.105V-1.111 |
| Horizontal Closed | |
| *Solid or Transparent* | *HCT.SC.M, HCS.SC.M* |
| All volumes | 0.05V+0.28 |

*Where V = Unit volume in cubic feet*

**Existing Equipment Efficiency**

| **Product Class** | **Refrigerator Energy when existing unit was manufactured before 03/26/2017**[728] ($kWh_{EXISTdailymax}$) | **Refrigerator Energy when existing unit was manufactured after 03/27/2017** ($kWh_{EXISTdailymax}$) |
|---|---|---|
| Vertical Closed | | |
| *Solid* | *VCS.SC.M* | *VCS.SC.M* |
| All volumes | 0.10V+2.04 | 0.05V+1.36 |
| *Transparent* | *VCT.SC.M* | *VCT.SC.M* |
| All volumes | 0.12V + 3.34 | 0.1V+0.86 |
| Horizontal Closed | | |
| *Solid* | *HCS.SC.M* | *HCS.SC.M* |
| All volumes | 0.10V+2.04 | *0.05V+0.91* |
| *Transparent* | *HCT.SC.M* | *HCT.SC.M* |
| All volumes | 0.12V + 3.34 | 0.06V+0.37 |

*Where V = Unit volume in cubic feet*

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[728] Code of Federal Regulations, Energy Efficiency Program for Certain Commercial and Industrial Equipment, title 10, sec. 431.66 (2010)..

# Night Covers for Refrigerated Cases

**Unique Measure Code(s): CI_RF_RF_NTCOV_0615**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

By covering refrigerated cases, the heat gain due to the spilling of refrigerated air and convective mixing with room air is reduced at the case opening. Continuous curtains can be pulled down overnight while the store is closed, yielding significant energy savings.

### Definition of Baseline Condition

In order for this characterization to apply, the baseline equipment is assumed to be a refrigerated case without a night cover.

### Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be a refrigerated case with a continuous cover deployed during overnight periods. Characterization assumes covers are deployed for six hours daily.

### Annual Energy Savings Algorithm

$$\Delta kWh = (LOAD / 12{,}000) * FEET * (3.516) / COP * ESF * 8{,}760.$$

$$\Delta kWh = 346.5 * FEET / COP.$$

*Where:*

*LOAD = average refrigeration load per linear foot of refrigerated case without night covers deployed.*
*= 1,500 BTU/h[729] per linear foot.*
*FEET = linear (horizontal) feet of covered refrigerated case.*
*12,000 = conversion factor - BTU per ton cooling.*
*3.516 = conversion factor – Coefficient of Performance (COP) to kW per ton.*
*COP = Coefficient of Performance of the refrigerated case.*
*= assume 2.2[730], if actual value is unknown.*
*ESF = Energy Savings Factor; reflects the percent reduction in refrigeration load due to the deployment of night covers*
*= 9%.[731]*

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[729] Davis Energy Group, Analysis of Standard Options for Open Case Refrigerators and Freezers, May 11, 2004. Accessed on 7/7/10 < http://www.energy.ca.gov/appliances/2003rulemaking/documents/case_studies/CASE_Open_Case_Refrig.pdf>

[730] Kuiken et al, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, KEMA, March 22, 2010.

[731] Effects of the Low Emissivity Shields on Performance and Power Use of a Refrigerated Display Case, Southern California Edison, August 8, 1997. Accessed on 7/7/10. <http://www.sce.com/NR/rdonlyres/2AAEFF0B-4CE5-49A5-8E2C-3CE23B81F266/0/AluminumShield_Report.pdf>; Characterization assumes covers are deployed for six hours daily.

*8,760* *= assumed annual operating hours of the refrigerated case.*

**Summer Coincident Peak kW Savings Algorithm**

$\Delta kW = 0$[732]

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 5 years.[733]

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[732] Assumed that the continuous covers are deployed at night; therefore no demand savings occur during the peak period.

[733] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

# Anti-Sweat Heater Controls

**Unique Measure Code(s): CI_RF_TOS_ASHC_0516**
**Effective Date: May 2016**
**End Date: TBD**

### Measure Description

Anti-sweat door heaters (ASDH) prevent condensation from forming on cooler and freezer doors. By installing a control device to turn off door heaters when there is little or no risk of condensation, significant energy savings can be realized. There are two commercially available control strategies – (1) ON/OFF controls and (2) micro pulse controls – that respond to a call for heating, which is typically determined using either a door moisture sensor or an indoor air temperature and humidity sensor to calculate the dew point. In the first strategy, the ON/OFF controls turn the heaters on and off for minutes at a time, resulting in a reduction in run time. In the second strategy, the micro pulse controls pulse the door heaters for fractions of a second, in response to the call for heating.

Both of these strategies result in energy and demand savings. Additional savings come from refrigeration interactive effects. When the heaters run less, they introduce less heat into the refrigerated spaces and reduce the cooling load.

### Definition of Baseline Condition

In order for this characterization to apply, the baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door running 24 hours a day, seven days per week (24/7) with no controls installed.

### Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be a door heater control on a commercial glass door cooler or refrigerator utilizing either ON/OFF or micro pulse controls.

### Annual Energy Savings Algorithm

$$\Delta kWh = kW_d * (\%ON_{NONE} - \%ON_{CONTROL}) * NUMdoors * HOURS * WHFe.$$

*Where:*

$kW_d$ = *connected load kW per connected door.*
= *If actual* $kW_d$ *is unknown, assume 0.13 kW.*[734]
$\%ON_{NONE}$ = *Effective run time of uncontrolled ASDH.*
= *assume 90.7%.*[735]
$\%ON_{CONTROL}$ = *Effective run time of ASDH with controls.*

---

[734] Cadmus. 2015. Commercial Refrigeration Loadshape Project. Lexington, MA.
[735] Ibid.

*= assume 58.9% for ON/OFF controls and 42.8% for micropulse controls.*[736]

*NUMdoors = number of reach-in refrigerator or freezer doors controlled by sensor.*

*= Actual number of doors controlled by sensor.*

*HOURS = Hours of operation.*

*= 8,760.*

*WHFe = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from heaters that must be rejected by the refrigeration equipment.*

*= assume 1.25 for cooler and 1.50 for freezer applications.*[737]

### Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = kW_d * WHFd * CF.$$

*Where:*

*WHFd = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from heatersthat must be rejected by the refrigeration equipment.*

*= assume 1.25 for cooler and 1.50 for freezer.*

*CF = Summer Peak Coincidence Factor.*

*= If site specific CFs are unkown, use deemed estimates in the table below.*[738]

| Control Type | $CF_{refrigerator}$ | $CF_{freezer}$ |
|---|---|---|
| On/Off Controls | 0.25 | 0.21 |
| Micropulse Controls | 0.36 | 0.30 |

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

The expected measure life is assumed to be 12 years.[739]

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[736] Ibid.

[737] Ibid. Coincidence factors developed by dividing the PJM Summer Peak kW Savings for ASDH Controls from Table 52 of the referenced report (0.041 kW/door for on/off controls and 0.58 kW/door for micropulse controls) by the product of the average wattage of ASDH per connected door (0.13 kW) and the Waste Heat Factor for Demand for either a refrigerator or a freezer.

[738] Ibid.

[739] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

# Evaporator Fan Electronically-Commutated Motor (ECM) Retrofit

**Unique Measure Code(s): CI_RF_RF_ECMFAN_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

Evaporator fans circulate air in refrigerated spaces by drawing air across the evaporator coil and into the space. Fans are found in both reach-in and walk-in coolers and freezers. Energy and demand savings for this measure are achieved by reducing motor operating power. Additional savings come from refrigeration interactive effects. Because electronically-commutated motors (ECMs) are more efficient and use less power, they introduce less heat into the refrigerated space compared to the baseline motors and result in a reduction in cooling load on the refrigeration system.

### Definition of Baseline Condition

This is defined as a retrofit measure. In order for this characterization to apply, the baseline condition is assumed to be an evaporator fan powered by a shaded pole (SP) motor that runs 24 hours a day, seven days per week (24/7) with no controls.

### Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be an evaporator fan powered by an ECM that runs 24/7 with no controls.

### Annual Energy Savings Algorithm

$$\Delta kWh = kW_{hp} * HP * \%\Delta_P * \%ON_{UC} * HOURS * WHFe.$$

*Where:*

$kW_{hp}$ = *ECM connected load kW per horsepower.*
= *If actual* $kW_{hp}$ *is unknown, assume 0.758 kW/hp.*[740]
HP = *Horsepower of ECM.*
= *Actual horsepower of ECM.*

$\%\Delta_P$ = *Percent change in power relative to ECM kW, calculated as the kW of the SP motor minus the kW of the ECM, divided by the kW of the ECM.*
= *If actual* $\%\Delta_P$ *is unknown, assume 157%.*[741]
$\%ON_{UC}$ = *Effective run time of uncontrolled motors.*
= *If actual* $\%ON_{UC}$ *is unknown, assume 97.8%.* [742]
*HOURS = Hours of operation.*
= *8,760.*

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[740] Cadmus. 2015. Commercial Refrigeration Loadshape Project. Lexington, MA.
[741] Ibid. Table 28
[742] Ibid. Table 34

*WHFe* = *Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.*
*= assume 1.38 for cooler and 1.76 for freezer applications.* [743]

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = kW_{hp} * HP * WHFd * CF.$$

*Where:*

*WHFd* = *Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.*
*= assume 1.38 for cooler and 1.76 for freezer applications.* [744]

*CF* = *Summer Peak Coincidence Factor.*
*= If site specific CFs are unknown, use 1.53.*[745]

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 15 years.[746]

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[743] Ibid. Table 54

[744] Ibid. Table 54

[745] Ibid. Coincidence factors developed by dividing the PJM Peak Savings for EF Motors and Controls from Table 47 of the referenced report (1.607 for a refrigerator and 2.048 for a freezer by the product of the average ECM wattage per rated horsepower (0.758 kW/hp) and the Waste Heat Factor for Demand for either a refrigerator or a freezer. Note: the CF is greater than one because it is calculated relative to the wattage of the post-retrofit ECM motor as opposed to the existing SP motor.

[746] Energy & Resource Solutions (ERS). 2005. Measure Life Study: prepared for The Massachusetts Joint Utilities

# Evaporator Fan Motor Controls

**Unique Measure Code(s): CI_RF_RF_EFCTRL_0516**
**Effective Date: May 2016**
**End Date: TBD**

### Measure Description

Evaporator fans circulate cool air in refrigerated spaces by drawing air across the evaporator coil and into the space. Uncontrolled, evaporator fans run 24 hours a day, seven days per week (24/7). Evaporator fan controls reduce fan run time or speed depending on the call for cooling, and therefore provide an opportunity for energy and demand savings. There are two commercially available strategies – (1) ON/OFF controls and (2) multispeed controls – that respond to a call for cooling. In the first strategy, the ON/OFF controls turn the motors on and off in response to the call for cooling, generating energy and demand savings as a result of a reduction in run time. In the second strategy, the multispeed controls change the speed of the motors in response to the call for cooling, saving energy and reducing demand by reducing operating power and run time (multispeed controls can also turn the motor off).

Additional savings come from the refrigeration interactive effects. Because fan controls reduce motor operating power and/or run time, they introduce less heat into the refrigerated space compared to uncontrolled motors and result in a reduction in cooling load on the refrigeration system.

### Definition of Baseline Condition

In order for this characterization to apply, the baseline condition is assumed to be an evaporator fan powered by an uncontrolled ECM or SP motor that runs 24/7.

### Definition of Efficient Condition

In order for this characterization to apply, the efficient equipment is assumed to be an evaporator fan powered by an ECM or SP motor utilizing either ON/OFF or multispeed controls.

### Annual Energy Savings Algorithm

$$\Delta kWh = kW_{hp} * HP * (\%ON_{UC} - \%ON_{CONTROL}) * HOURS * WHFe$$

*Where:*

$kW_{hp}$ = *connected load kW per horsepower of motor.*
= *If actual* $kW_{hp}$ *is unknown, assume 0.758 kW/hp for ECM and 2.088 kW/hp for SP motor.*[747]

HP = *Horsepower of ECM or SP motor.*
= *Actual horsepower of ECM or SP motor.*

$\%ON_{UC}$ = *Effective run time of uncontrolled motor*
= *If actual* $\%ON_{UC}$ *is unkown, assume 97.8%.* [748]

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[747] Cadmus. 2015. Commercial Refrigeration Loadshape Project. Lexington, MA.
[748] Ibid.

*$\%ON_{CONTROL}$ = Effective run time of motor with controls.*
*= Assume 63.6% for ON/OFF style controls and 69.2% for multi-speed style controls.* [749]
*HOURS = Hours of operation.*
*= 8,760.*
*WHFe = Waste Heat Factor for Energy; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.*
*= assume 1.38 for cooler and 1.76 for freezer applications.*[750]

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = kW_{hp} * HP * WHFd * CF$$

*Where:*
*WHFd = Waste Heat Factor for Demand; represents the increased savings due to reduced waste heat from motors that must be rejected by the refrigeration equipment.*
*= assume 1.38 for cooler and 1.76 for freezer applications.*[751]
*CF = Summer Peak Coincidence Factor.*
*= If site specific CFs are unkown, use 0.26.*[752]

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The expected measure life is assumed to be 10 years.[753]

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[749] Ibid.

[750] Ibid.

[751] Ibid.

[752] Ibid. Coincidence factors developed by dividing the PJM Peak Savings for EF Motors and Controls from Table 47 of the referenced report by the product of the average baseline motor wattage per rated horsepower (0.758 kW/hp for ECM and 2.088 kW/hp for SP) and the Waste Heat Factor for Demand.

[753] Energy & Resource Solutions (ERS). 2005. Measure Life Study: prepared for The Massachusetts Joint Utilities.

# Refrigeration Door Gasket Replacement

**Unique Measure Code(s): CI_RF_RF_RGasket_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes the replacement of damaged refrigeration door gaskets with new sealing gaskets for walk-in or reach-in refrigeration units in either an unconditioned space or in a conditioned space where the condensing unit is also in the conditioned space. A walk-in unit housed in a mechanically cooled space, but where the condenser is located outside is not eligible since the leak is acting as a localized air conditioner, reducing the load of the space cooling system.

### Definition of Baseline Condition

This is defined as a retrofit measure. The baseline condition is an old and/or damaged gasket with at least six inches of damage for reach-in units and at least two feet of damage for walk-in units.[754]

### Definition of Efficient Condition

The efficient condition is a new complete gasket.

### Annual Energy Savings

$$\Delta kWh = SPF_e * L$$

*Where:*

*$SPF_e$ = Annual Energy Savings per Foot of gasket, given in the table below.*

| Refrigeration Type | Energy Savings (kWh /foot)[755] |
|---|---|
| Low Temp (Freezer) Reach-in | 27.3 |
| Med Temp (Cooler) Reach-in | 18.2 |
| Low Temp (Freezer) Walk-in | 33.1 |
| Med Temp (Cooler) Walk-in | 18.0 |

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[754] BPA sponsored Emerson study. "Study of Typical Gasket Deterioration", Feb 27, 2008, Emerson Design Services Network. https://slideplayer.com/slide/4525301/

[755] BPA sponsored Emerson study. "Study of Typical Gasket Deterioration", Feb 27, 2008, Emerson Design Services Network. https://slideplayer.com/slide/4525301/.

*L* = *total length of gasket being replaced, in feet. Note: This is independent of the damaged portion of gasket. If unknown, assume 15 feet for reach-in units and 20 feet for walk-in units.*

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = SPF_d * L$$

*Where:*

$SPF_d$ = *Demand Savings per Foot of gasket*

| Refrigeration Type | Peak Demand Reduction (kW /foot)[756] |
|---|---|
| Low Temp (Freezer) Reach-in | 0.001928 |
| Med Temp (Cooler) Reach-in | 0.000829 |
| Low Temp (Freezer) Walk-in | 0.001911 |
| Med Temp (Cooler) Walk-in | 0.000822 |

**Annual Fossil Fuel Savings Algorithm**

n/a

**Annual Water Savings Algorithm**

n/a

**Measure Life**

The measure life is assumed to be 4 years.[757]

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[756] Analysis of results from BPA sponsored Emerson study, "Study of Typical Gasket Deterioration", Feb 27, 2008, Emerson Design Services Network https://slideplayer.com/slide/4525301/ and Pennsylvania TRM 2016.

[757] Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, California Public Utility Commission, February 2010.

*Hot Water End Use*

# C&I Heat Pump Water Heater

**Unique Measure Code(s): CI_WT_TOS_HPCIHW_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a Heat Pump water heater in place of a standard electric water heater. This measure applies to time of sale and new construction opportunities.

### Definition of Baseline Condition

The baseline condition is a standard electric water heater.

### Definition of Efficient Condition

The efficient condition is a heat pump water heater.

### Annual Energy Savings Algorithm

$$\Delta kWh = (kBTU\_req / 3.413) * ((1/EFbase) - (1/EFee))$$

*Where:*

*kBTU_req (Office)* = *Required annual heating output of office (kBTU)*
= *6,059.*[758]
*kBTU_req (School)* = *Required annual heating output of school (kBTU)*
= *22,191.*[759]
*3.413* = *Conversion factor from kBTU to kWh.*
*EFee* = *Energy Factor of Heat Pump domestic water heater.*
= *2.0.* [760]
*EFbase* = *Energy Factor of baseline domestic water heater.*
= *0.904.* [761]

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[758] 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.

[759] 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.

[760] 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

[761] Ibid.

ΔkWh Office = (6,059 / 3.413) * ((1/0.904) – (1/2.0)).
= 1076.2 kWh.

ΔkWh School = (22,191 / 3.413) * ((1/0.904) – (1/2.0)).
= 3941.4 kWh.

If the deemed "kBTU_req" estimates are not applicable, the following equation can be used to estimate annual water heating energy requirements:

*kBTU_req = GPD * 8.33 * 1.0 * WaterTempRise * 365 /1000.*

*Where:*

*GDP = Average daily hot water requirements (gallons/day).*
*= Actual usage (Note: days when the building is unoccupied must be included in the averaging calculation).*
*8.33 = Density of water (lb/gallon).*
*1.0 = Specific heat of water (BTU/lb-°F).*
*WaterTempRise = Difference between average temperature of water delivered to site and water heater setpoint (°F).*
*365 = Days per year.*

**Summer Coincident Peak kW Savings Algorithm**

ΔkW = ΔkWh / Hours * CF

*Where:*

*Hours (Office) = Run hours in office.*
*= 5885.* [762]
*Hours (School) = Run hours in school.*
*= 2218.* [763]
*CF (Office) = Summer Peak Coincidence Factor for office measure.*
*= 0.630.* [764]
*CF (School) = Summer Peak Coincidence Factor for school measure.*
*= 0.580.* [765]

ΔkW Office = (1076.2 / 5885) * 0.630.
= 0.12 kW.
ΔkW School = (3941.4 / 2218) * 1.03
= 1.03 kW.

If annual operating hours and CF estimates are unknown, use deemed HOURS and CF estimates above. Otherwise, use site specific values.

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[762] Calculated from Itron eShapes, which is 8760 hourly data by end use for Upstate New York.
[763] Ibid.
[764] Ibid.
[765] Ibid.

## Annual Fossil Fuel Savings Algorithm

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 10 years.[766]

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

# Pre-Rinse Spray Valves

**Unique Measure Code(s): CI_WT_RF_PRSPRY_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

All pre-rinse valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. They reduce water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The spray valves usually have a clip to lock the handle in the “on” position. Pre-rinse valves are inexpensive and easily interchangeable with different manufacturers’ assemblies. The primary impacts of this measure are water savings. Energy savings depend on the facility’s water heating fuel - if the facility does not have electric water heating, there are no electric savings for this measure; if the facility does not have fossil fuel water heating, there are no MMBTU savings for this measure.

### Definition of Baseline Condition

This is defined as a retrofit measure. The baseline equipment is assumed to be an existing spray valve with a flow rate of 3 gallons per minute.

### Definition of Efficient Condition

The efficient equipment is assumed to be a pre-rinse spray valve with a flow rate of 1.6 gallons per minute, and with a cleanability performance of 26 seconds per plate or less.

### Annual Energy Savings Algorithm

$$\Delta kWh = \Delta Water \text{ x } HOT\% \text{ x } 8.33 \text{ x } (\Delta T) \text{ x } (1/EFF) / 3413.$$

*Where:*

*ΔWater* = *Water savings (gallons); see calculation in “Water Impact” section below.*

*$HOT_{\%}$* = *The percentage of water used by the pre-rinse spray valve that is heated.*
= *69%.*[767]

*8.33* = *The energy content of heated water (BTU/gallon/°F).*

*ΔT* = *Temperature rise through water heater (°F).*
= *70.*[768]

*EFF* = *Water heater thermal efficiency.*
= *0.97.*[769]

*3413* = *Factor to convert BTU to kwh.*

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[767] Measures and Assumptions for DSM Planning (2009). Navigant Consulting. Prepared for the Ontario Energy Board. This factor is a candidate for future improvement through evaluation.

[768] Engineering judgment; assumes typical supply water temperature of 70°F and a hot water storage tank temperature of 140°F.

[769] Federal Standards. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/51

**Summer Coincident Peak kW Savings Algorithm**

$$\Delta kW = 0$$

**Annual Fossil Fuel Savings Algorithm**

$$\Delta MMBTU = \Delta Water \times HOT\% \times 8.33 \times (\Delta T) \times (1/EFF) \times 10^{-6}$$

*Where:*

*EFF = Water heater thermal efficiency.*
*= 0.75*[770]*.*
*$10^{-6}$ = Factor to convert BTU to MMBTU.*

**Annual Water Savings Algorithm**

$$\Delta Water = (FLO_{base} – FLO_{eff}) \times 60 \times HOURS_{day} \times 365$$

*Where :*

*ΔWater = Annual water savings (gal).*
*$FLO_{base}$ = The flow rate of the baseline spray nozzle.*
*= 3 gallons per minute.*
*$FLO_{eff}$ = The flow rate of the efficient equipment.*
*= 1.6 gallons per minute.*
*60 = minutes per hour.*
*365 = days per year.*
*HOURS = Hours used per day – depends on facility type as below:*[771]

| **Facility Type** | **Hours of Pre-Rinse Spray Valve Use per Day (HOURS)** |
|---|---|
| Full Service Restaurant | 4 |
| Other | 2 |
| Limited Service (Fast Food ) Restaurant | 1 |

**Measure Life**

The measure life is assumed to be 5 years.[772]

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[770] IECC 2006. Performance requirement for gas water heaters.

[771] Hours estimates based on *PG&E savings estimates, algorithms, sources* (2005). Food Service Pre-Rinse Spray Valves

[772] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Effective/Remaining Useful Life Values”, California Public Utilities Commission, December 16, 2008.

# High Efficiency Commercial Gas Storage Water Heater >75kBtu

**Unique Measure Code(s): CI_WT_TOS_GASHW_HI _0420**
**Effective Date: April 2020**
**End Date: TBD**

**Measure Description**

This measure applies to the installation of stand-alone, gas-fired, commercial storage water heaters with an input rating of >75,000 BTU/hour and <4,000 Btus/hr per gallon of stored water, that meet or exceed ENERGY STAR criteria. It is not intended for equipment that delivers process or space heating hot water. The high efficiency unit would be installed at time of sale instead of a new unit rated at the minimum federal efficiency standard.

**Definition of Baseline Condition**

The baseline condition is a new conventional, commercial gas storage water heater, >75kBtu meeting prevailing federal code minimum efficiency standards[773], effective after October 9, 2015. See Efficiency Criteria Table below.

**Definition of Efficient Condition**

The installed efficient equipment is a direct fired, stand-alone gas water heater >75kBtu input, meeting or exceeding ENERGY STAR v2.0 specifications[774] effective October 1, 2018. See Efficiency Criteria Table below.

| Commercial Gas Storage Water Heater >75kBtu, Efficiency Criteria | | | |
|---|---|---|---|
| **Condition** | **Equipment Description** | **Maximum Standby Loss (Btu/hr)** | **Minimum Thermal Efficiency (TE)** |
| Baseline | Gas-fired storage water heater meeting prevailing federal code | IR/800 + 110 * (Vs^.5) | 80% |
| Efficient[775] | Gas-fired storage water heaters meeting ENERGY STAR criteria | ≤0.84 * [IR/800 + 110 * (Vs^.5)] | ≥94% |

**Annual Fossil Fuel Savings Algorithm**

Annual MMBTU savings is the sum of standby loss savings and thermal efficiency savings.

ΔMMBtu = ΔMMBtu = ΔStandby Loss + ΔTE
= ((Standby Loss of baseline unit) – (Standby Loss of efficient unit) * 8,760 / 1000,000)

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[773] Federal minimum standards for standby loss and TE CFR Title 10 → Chapter II → Subchapter D → Part 431 Subpart G

[774] ENERGY STAR Commercial Water Heater Key Product Criteria

[775] ENERGY STAR Commercial Water Heater eligibility criteria v2.0

\+ ((Thermal Efficiency of baseline unit) – (Thermal Efficiency of efficient unit))

= ((IR/800 + 110 * (Vs^$^{.5}$)) – (.84 * IR/800 + 110 * (Vs^$^{.5}$))* 8,760 / 1,000,000)
\+ (MMBTU/yr$_{act}$ x (1-(TE$_{base}$ / TE$_{eff}$)))

*Where:*

*IR = Input rate (BTU/hr) of efficient WH*
*Note: IR of the baseline unit and efficient units must be the same for correct savings.*

*Vs = rated storage volume (gallons) of new, efficient water heater*

*.84 = maximum allowable percent of efficient unit standby loss relative to baseline*

*TEe = Thermal Efficiency of baseline unit*

*TEeff = Thermal Efficiency of efficient unit*

*MMBTU/yract = existing annual water heating energy consumed, actual (measured or calculated)*

*8,760 = hours in a year*

*1,000,000 = conversion from BTU to MMBTU*

**Example Calculation**
The following example is shown to calculate the annual energy savings of a new, energy efficient, direct fired, 100 gallon, 150kBtu stand-alone gas water heater with a TE of 96% and standby loss rated at 1,000 Btu/hr. as compared to minimum federal efficiency standard of 80% TE installed at time of natural replacement. The existing water heater was estimated to consume 200 MMBtu/year.

**Standby Loss of baseline unit (Max)**
Btu/hr = IR / 800 + 110 * (Vs^.5)
= 150,000/800 + 110 * (100^.5)
= 1,287.5 Maximum allowable

**Standby Loss of efficient unit (Max)**
Btu/hr = .84 * IR / 800 + 110 * (Vs^.5)
= .84 * 150,000/800 + 110 * (100^.5)
= 1,081.5 Maximum allowable
= 1,000 as rated (rated takes precedence)

**Annual Standby Loss Savings**
ΔMMBtu = (standby loss of efficient unit – standby loss of baseline unit) * 8,760 / 1,000,000
= (1,287.5 – 1,000) * 8,760 / 1,000,000

= 2.5 MMBtu/yr savings

**Annual Thermal Efficiency Savings**

ΔMMBtu = $\text{MMBtu/yr}_{act}$ x $(1-(TE_{base} / TE_{eff}))$
= 200 * (1-(.80 / .96))
= 33.3

**Total Annual Savings**

Total Annual MMBtu Savings = Annual Standby Loss Savings + Annual Thermal Efficiency Savings
= 2.5 + 33.3
= 35.8 MMBtu

**Measure Life**

The measure life is assumed to be 10 years[776]

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[776] EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018

# High Efficiency Commercial Gas Storage Water Heater ≤75kBtu

**Unique Measure Code(s): CI_WT_TOS_GASHW_HI _0619**
**Effective Date: June 2019**
**End Date: TBD**

### Measure Description

This measure applies to the installation of stand-alone, gas-fired, storage water heaters used in commercial applications with an input rating of ≤75,000 BTU/hour that meet or exceed ENERGY STAR criteria. It is not intended for equipment that delivers process or space heating hot water. The high efficiency unit would be installed at time of sale instead of a new unit rated at the minimum federal standard.

### Definition of Baseline Condition

The baseline condition is a new, conventional gas-fired storage water heater, ≤75kBtu input, with a rated storage volume between 20 and 100 gallons, meeting prevailing federal code minimum efficiency standards[777] for consumer products (due to ≤75kBtu input rating) referencing the Uniform Energy Factor (UEF) energy performance criteria. This specification became effective December 29, 2016[778].

### Definition of Efficient Condition

The installed efficient equipment is a stand-alone, gas-fired storage water heater, ≤75kBtu input, with a rated storage volume between 20 and 100 gallons, that meets or exceeds ENERGY STAR water heater requirements Version 3.2[779], referencing Energy Factor (EF) or Uniform Energy Factor[780] (UEF) energy performance criteria, effective April 16, 2015.

| **Commercial Gas Storage Water Heater ≤75kBtu Efficiency Criteria** | | | | | | |
|---|---|---|---|---|---|---|
| | *ENERGY STAR allows for qualification with EF or UEF (see ES v3.2 Specs)* | | **Min. Uniform Energy Factor (UEF)** based on hot water draw pattern | | | |
| **Condition** | **Storage Volume (Vs)** | **Min. Energy Factor (EF)** | *very small 10 GPD* | *low 38 GPD* | *medium 55 GPD* | *high 84 GPD* |
| Baseline (min fed standard) | ≥20 and ≤55 gal | 0.675-(0.0015 * Vs) | 0.3456 – (0.0020 * Vs) | 0.5982 – (0.0019 * Vs) | 0.6483 – (0.0017 * Vs) | 0.692 – (0.0013 * Vs) |
| | >55 gal and ≤100 gal | 0.8012-(0.00078 * Vs) | 0.6470 – (0.0006 * Vs) | 0.7689 – (0.0005 * Vs) | 0.7897 – (0.0004 × Vs) | 0.8072 – (0.0003 * Vs) |
| Efficient | ≤55 gal | ≥0.67 | NA | NA | ≥0.64 | ≥0.68 |

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[777] Title 10 → Chapter II → Subchapter D → Part 430 → Subpart C → §430.32

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

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

[780] Title 10 → Chapter II → Subchapter D → Part 430 Appendix E

| | | | | | | |
|---|---|---|---|---|---|---|
| | >55 gal | ≥0.77 | NA | NA | ≥0.78 | ≥0.80 |

**Determining Draw Pattern**

The relevant hot water draw pattern is specific to the installed location. If actual draw pattern is not known, it can be estimated from the water heater's first hour rating[781] per table below.
If first hour rating is unknown, use medium draw pattern with rated storage capacity ≤50 gallons, and high draw pattern if >50 gallons.[782]

| Draw Pattern based on First Hour Rating | |
|---|---|
| **First Hour Rating** | **Draw Pattern** |
| <18 gallons | Very Small |
| =18 and <51 gallons | Low |
| =51 and <75 gallons | Medium |
| ≥75 gallons | High |

**Annual Fossil Fuel Savings Algorithm, UEF Method**

$\Delta MMBTU = MMBtu/yr_{act} * UEF_{base} * (1/ UEF_{base} – 1/UEF_{eff})$

**Annual Fossil Fuel Savings Algorithm, EF Method**

$\Delta MMBTU = MMBtu/yr_{act} * EF_{base} * (1 / EF_{base} – 1 / EF_{eff})$

*Where:*

*$MMBtu/yr_{act}$ = existing annual water heating energy consumed, actual (measured or calculated)*
*$UEF_{base}$ = Uniform Energy Factor of baseline water heater*
*= as-rated based on draw pattern OR*
*If unknown, calculate using values from "Draw Pattern based on First Hour Rating" table and additional algorithm from "Efficiency Criteria" table above.*
*$UEF_{eff}$ = Uniform Energy Factor of efficient water heater*
*$EF_{base}$ = Energy Factor of baseline water heater*
*$EF_{eff}$ = Energy Factor of efficient water heater*
*Vs = rated storage volume (gallons)*

Example to calculate the annual energy savings of a new energy efficient direct fired, 55 gallon stand-alone gas water heater with a UEF of .68 and an estimated annual consumption of 50MMBTU/yr.
This water draw pattern is known to be high. The baseline unit is the same size and meets the minimum federal standard UEF of .62 as calculated from the Efficiency Criteria table above.

$\Delta MMBTU = 50\ MMBtu/yr_{act} * .62 * (1/.62 – 1/.68)$
$= 31 * .14$
$= 4.41$ MMBtu/yr savings

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[781] CFR part 430 App E 5.4.1

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

**Measure Life**

The measure life is assumed to be 13 years[783]

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[783] EIA Updated Buildings Sector Appliance and Equipment Costs and Efficiencies, June 2018 (average)

*Appliance End Use*

# Commercial Clothes Washer

**Unique Measure Code(s): CI_LA_TOS_CCWASH_0516**
**Effective Date: May 2016**
**End Date: TBD**

## Measure Description

This measure relates to the purchase (time of sale) and installation of a commercial clothes washer (i.e., soft-mounted front-loading or soft-mounted top-loading clothes washer that is designed for use in applications in which the occupants of more than one household will be using the clothes washer, such as multi-family housing common areas and coin laundries) exceeding the ENERGY STAR minimum qualifying efficiency standards presented below:[784]

| Efficiency Level | Modified Energy Factor (MEF) | Water Factor (WF) |
|---|---|---|
| ENERGY STAR | >= 2.2 | <= 4.5 |

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

The Water Factor (WF) is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

## Definition of Baseline Condition

The baseline efficiency is determined according to the Modified Energy Factor (MEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle. The federal baseline MEF as of May 2016 is 1.60 for top loading units and 2.00 for front loading units. Beginning January 1, 2018, the federal standards increase to 1.35 for top loading units and remain 2.00 for front loading units.

## Definition of Efficient Condition

The efficient condition is a clothes washer meeting the ENERGY STAR efficiency criteria presented above.

## Annual Energy Savings Algorithm

$$\Delta kWh = \Delta kWh_{CW} + \Delta kWh_{DHW} + \Delta kWh_{DRYER}$$

$$\Delta kWh_{CW} = (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE}) * \%CW$$

$$\Delta kWh_{DHW} = (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE}) * \%DHW * DHW_{ELEC}$$

$$\Delta kWh_{DRYER} = [(kWh_{TOTAL,BASE} - kWh_{TOTAL,EE}) - (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE})] * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE\_MOD} * DRYER_{ELEC}$$

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[784] U.S. EPA. 2015. ENERGY STAR® Program Requirements Product Specification for Clothes Washers Eligibility Criteria Version 7.1

$$kWh_{UNIT,i} = kWh_{UNIT\_RATED,i} * Ncycles / Ncycles\_ref$$

$$kWh_{TOTAL,i} = Capacity / MEF_i * Ncycles$$

*Where*

*$i$ = Subscript denoting either baseline ("BASE") or efficient ("EE") equipment.*

*$\Delta kWh_{CW}$ = Clothes washer machine electric energy savings.*

*$\Delta kWh_{DHW}$ = Water heating electric energy savings.*

*$\Delta kWh_{DRYER}$ = Dryer electric energy savings.*

*$kWh_{UNIT, BASE}$ = Conventional unit electricity consumption exclusive of required dryer energy.*

*$kWh_{UNIT, EE}$ = ENERGY STAR unit electricity consumption exclusive of required dryer energy.*

*$kWh_{TOTAL, BASE}$ = Conventional unit electricity consumption inclusive of required dryer energy (assuming electric dryer).*

*$kWh_{TOTAL, EE}$ = ENERGY STAR unit electricity consumption inclusive of required dryer energy (assuming electric dryer).*

*$kWh_{UNIT\_RATED, BASE}$ = Conventional rated unit electricity consumption.*
*= If actual value unknown, assume 241 kWh/yr.*[785]

*$kWh_{UNIT\_RATED, EE}$ = Efficient rated unit electricity consumption.*
*= If actual value unknown, assume 97 kWh/yr.*[786]

*%CW = Percentage of unit energy consumption used for clothes washer operation.*
*= If unknown, assume 20%.*[787]

*%DHW = Percentage of unit energy consumption used for water heating.*
*= If unknown, assume 80%.*[788]

*$DHW_{ELEC}$ = 1 if electric water heating; 0 if gas water heating.*

*$MEF_{BASE}$ = Modified Energy Factor of baseline unit.*
*= Values provided in table below.*

*$MEF_{EE}$ = Modified Energy Factor of efficient unit.*
*= Actual. If unknown assume average values provided below.*

*Capacity = Clothes washer capacity (cubic feet).*
*= Actual. If capacity is unknown assume average 3.43 cubic feet.*[789]

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[785] U.S. EPA. 2016. Savings Calculator for ENERGY STAR Qualified Appliances. Accessed March 7, 2016. http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

[786] Ibid.

[787] Ibid.

[788] Ibid.

789 Based on the average commercial clothes washer volume of all units meeting ENERGY STAR V7.1 criteria listed in the ENERGY STAR database of certified products accessed on 03/07/2016. https://www.energystar.gov/productfinder/product/certified-commercial-clothes-washers/results.

| Efficiency Level | Modified Energy Factor (MEF) | |
|---|---|---|
| | Front Loading | Top Loading |
| Federal Standard | Before January 1, 2018 | |
| | >= 2.00 | >= 1.60 |
| | On or After January 1, 2018 | |
| | >= 2.00 | >= 1.35 |
| ENERGY STAR | >= 2.20 | |

*Ncycles = Number of cycles per year.*
*= If actual value unknown, assume 1,241 for multifamily applications and 2,190 for landromats.*[790]
*Ncycles_ref = Reference number of cycles per year.*
*= 392.*[791]
$\%LOADS_{DRYED}$ *= Percentage of washer loads dried in machine.*
*= If actual value unknown, assume 100%.*
$DRYER_{USAGE}$ *= Dryer usage factor.*
*= 0.84.*[792]
$DRYER_{USAGE\_MOD}$ *= Dryer usage in buildings with dryer and washer*
*= 0.95.*[793]
$DRYER_{ELEC}$ *= 1 if electric dryer; 0 if gas dryer.*

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

**Summer Coincident Peak kW Savings Algorithm**

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

*Where:*

*Hours = Assumed Run hours of Clothes Washer.*
*= 265.* [794]
*CF = Summer Peak Coincidence Factor for measure*
*= 0.029.* [795]

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[790] U.S. EPA. 2016. Savings Calculator for ENERGY STAR Qualified Appliances. Accessed March 7, 2016. http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

[791] Ibid.

[792] Ibid.

[793] Ibid.

[794] Metered data from Navigant Consulting "EmPOWER Maryland Draft Final Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Appliance Rebate Program." March 21, 2014, page 36. This data applies to residential applications. In the absence of metered data specific to multifamily common area and commercial laundromat applications, this coincidence value is used as a proxy given consistency with the PJM peak definition; however, this value is likely conservatively low for commercial applications and is a candidate for update should more applicable data become available.

[795] Ibid.

**Annual Fossil Fuel Savings Algorithm**

$$\Delta MMBTU = \Delta MMBTU_{DHW} + \Delta MMBTU_{DRYER}$$

$$\Delta MMBTU_{DHW} = (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE}) * \%DHW / DHW_{EFF} * MMBTU\ \_convert * DHW_{GAS}$$

$$\Delta MMBTU_{DRYER} = [(kWh_{TOTAL,BASE} - kWh_{TOTAL,EE}) - (kWh_{UNIT,\ BASE} - kWh_{UNIT,\ EE})] * MMBTU\ \_convert * \%LOADS_{DRYED} / DRYER_{USAGE} * DRYER_{USAGE\_MOD} * DRYER_{GAS,CORR} * DRYER_{GAS}$$

*Where:*

*$\Delta MMBTU_{DHW}$ = Water heating gas energy savings*
*$\Delta MMBTU_{DRYER}$ = Dryer gas energy savings*
*$DHW_{EFF}$ = Gas water heater efficiency.*
*= If actual unknown, assume 75%.*
*MMBTU _convert = Convertion factor from kWh to MMBTU.*
*= 0.003413.*
*$DHW_{GAS}$ = 1 if gas water heating; 0 if electric water heating.*
*$DRYER_{GAS,CORR}$ = Gas dryer correction factor; 1.12.*[796]
*$DRYER_{GAS}$ = 1 if gas dryer; 0 if electric dryer.*

**Annual Water Savings Algorithm**

$$\Delta Water\ (CCF) = Capacity * (WF_{BASE} - WF_{EE}) * Ncycles / 748$$

*Where*

*$WF_{BASE}$ = Water Factor of baseline clothes washer.*
*= Values provided below.*
*$WF_{EE}$ = Water Factor of efficient clothes washer.*
*= Actual. If unknown assume value provided below.*
*748 = Conversion factor from gallons to CCF.*

| Efficiency Level | Water Factor (WF) | |
|---|---|---|
| | Front Loading | Top Loading |
| Federal Standard | Before January 1, 2018 | |
| | <= 5.5 | <= 8.5 |
| | On or After January 1, 2018 | |
| | <= 4.1 | <= 8.8 |
| ENERGY STAR | <= 4.5 | |

KWh Savings from Water Reduction

The kWh savings from the waste reduction characterized above is now estimated. Please note that utilities' must be careful not to double count the monetary benefit of these savings within

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[796] U.S. EPA. 2016. Savings Calculator for ENERGY STAR Qualified Appliances. Accessed March 7, 2016. http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx

cost effectiveness testing if the avoided costs of water already include the associated electric benefit.

$$\Delta kWh_{water}{}^{797} = 2.07\ kWh/CCF * \Delta Water\ (CCF)$$

**Measure Life**

The measure life is assumed to be 7 years. [798]

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[797] This savings estimate is based upon VEIC analysis of data gathered in audit of DC Water Facilities, MWH Global, "Energy Savings Plan, Prepared for DC Water." Washington, D.C., 2010. See DC Water Conservation.xlsx for calculations and DC Water Conservation Energy Savings_Final.doc for write-up. This is believed to be a reasonably proxy for the entire region.

[798] Ibid

*Plug Load End Use*

# Tier 1 Advanced Power Strip

**Unique Measure Code: CI_PL_TOS_APS_0614**
**Effective Date: June 2014**
**End Date: TBD**

## Measure Description

This measure relates to the installation of a Current-Sensing Master/Controlled Advanced Power Strip (APS) in place of a standard "power strip," a device used to expand a single wall outlet into multiple outlets. This measure is assumed to be a time of sale installation.

## Definition of Baseline Condition

The baseline condition is a standard "power strip". This strip is simply a "plug multiplier" that allows the user to plug in multiple devices using a single wall outlet. Additionally, the baseline unit has no ability to control power flow to the connected devices.

## Definition of Efficient Condition

The efficient condition is a Current-Sensing Master/Controlled Advanced Power Strip that functions as both a "plug multiplier" and also as a plug load controller. The efficient unit has the ability to essentially disconnect controlled devices from wall power when the APS detects that a controlling device, or master load, has been switched off. The efficient device effectively eliminates standby power consumption for all controlled devices[799] when the master load is not in use.

## Annual Energy Savings Algorithm

$\Delta kWh = 26.9\ kWh$[800]

## Summer Coincident Peak kW Savings Algorithm

$\Delta kW = 0\ kW$

## Annual Fossil Fuel Savings Algorithm

n/a

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[799] Most advanced power strips have one or more uncontrolled plugs that can be used for devices where a constant power connection is desired such as fax machines and wireless routers.

[800] Energy & Resource Solutions. 2013. Emerging Technologies Research Report; Advanced Power Strips for Office Environments prepared for the Regional Evaluation, Measurement, and Verification Forum facilitated by the Northeast Energy Efficiency Partnerships." Assumes savings consistent with the 20W threshold setting for the field research site (of two) demonstrating higher energy savings. ERS noted that the 20 W threshold may be unreliable due to possible inaccuracy of the threshold setting in currently available units. It is assumed that future technology improvements will reduce the significance of this issue. Further, savings from the site with higher average savings was adopted (26.9 kWh versus 4.7 kWh) acknowledging that investigations of APS savings in other jurisdictions have found significantly higher savings. For example, Northwest Power and Conservation Council, Regional Technical Forum. 2011. "Smart Power Strip Energy Savings Evaluation" found average savings of 145 kWh.

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 4 years.[801]

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[801] David Rogers, Power Smart Engineering, "Smart Strip Electrical Savings and Usability," October 2008.

*Commercial Kitchen Equipment End Use*

# Commercial Fryers

## Unique Measure Code(s): CI_KE_TOS_FRY_0420
## Effective Date: April 2020
## End Date: TBD

### Measure Description

Commercial fryers that have earned the ENERGY STAR offer shorter cook times and higher production rates through advanced burner and heat exchanger designs. Frypot insulation reduces standby losses resulting in a lower idle energy rate. This measure applies to both standard sized fryers and large vat fryers.[802] Standard sized fryers that have earned the ENERGY STAR are up to 30% more efficient than non-qualified models; large vat fryers are 35% more efficient. This measure applies to time of sale opportunities.

### Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency electric fryer with a heavy load efficiency of 75% for standard sized equipment and 70% for large vat equipment or a gas fryer with heavy load efficiency of 35% for both standard sized and large vat equipment.

### Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified electric or gas fryer.[803]

### Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} – LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} – LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*[804]

*i* = *either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.*

*$kWh\_Cooking_i$ = daily cooking energy consumption (kWh).*

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[802] Standard fryers measures >12 inches and < 18 inches wide, and have shortening capacities > 25 pounds and < 65 pounds. Large vat fryers measure > 18 inches and < 24 inches wide, and have shortening capacities > 50 pounds.

[803] US EPA. December 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Fryers Eligibility Criteria Version 3.0

[804] Unless otherwise noted, all default assumptions are from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

*$kWh\_Idle_i$* = *daily idle energy consumption (kWh).*

*$kWh_{base}$* = *the annual energy usage of the baseline equipment calculated using baseline values.*

*$kWh_{eff}$* = *the annual energy usage of the efficient equipment calculated using efficient values.*

*$HOURS_{DAY}$* = *average daily operating hours.*
= *if average daily operating hours are unknown, assume default of 16 hours/day for standard fryers and 12 hours/day for large vat fryers.*

*$E_{FOOD}$* = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.167.*

*LB* = *Pounds of food cooked per day (lb/day).*
= *if average pounds of food cooked per day is unknown, assume default of 150 lbs/day.*

*DAYS* = *annual days of operation.*
= *if annual days of operation are unknown, assume default of 365 days.*

*EFF* = *Heavy load cooking energy efficiency (%).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*IDLE* = *Idle energy rate (kW).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*PC* = *Production capacity (lb/hr).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

**Electric Fryer Performance Metrics: Baseline and Efficient Values**

| | Standard Size | | Large Vat | |
|---|---|---|---|---|
| **Parameter** | **Baseline Model** | **Energy Efficient Model** | **Baseline Model** | **Energy Efficient Model** |
| IDLE (kW) | 1.05 | 0.80 | 1.35 | 1.10 |
| EFF | 75% | 83% | 70% | 80% |
| PC | 65 | 70 | 100 | 110 |

### Summer Coincident Peak kW Savings Algorithm [805]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

### Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$

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[805] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

$$MMBTU\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

*Where:*[806]

$MMBTU\_Cooking_i$ = *daily cooking energy consumption (MMBTU).*
$MMBTU\_Idle_i$ = *daily idle energy consumption (MMBTU).*
$MMBTU_{base}$ = *the annual energy usage of the baseline equipment calculated using baseline values.*
$MMBTU_{eff}$ = *the annual energy usage of the efficient equipment calculated using efficient values.*
$E_{FOOD}$ = *ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.00057.*
*IDLE* = *Idle energy rate (MMBTU/h).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

**Gas Fryer Performance Metrics: Baseline and Efficient Values**

| **Parameter** | **Standard Size** | | **Large Vat** | |
|---|---|---|---|---|
| | **Baseline Model** | **Energy Efficient Model** | **Baseline Model** | **Energy Efficient Model** |
| IDLE (MMBTU/h) | 0.014 | 0.009 | 0.016 | 0.012 |
| EFF | 35% | 50% | 35% | 50% |
| PC | 60 | 65 | 100 | 110 |

### Annual Water Savings Algorithm

n/a

### Measure Life

12 years[807]

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[806] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[807] US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

# Commercial Steam Cookers

## Unique Measure Code(s): CI_KE_TOS_STMR_0615
## Effective Date: June 2015
## End Date: TBD

### Measure Description

Energy efficient steam cookers that have earned the ENERGY STAR label offer shorter cook times, higher production rates, and reduced heat loss due to better insulation and more efficient steam delivery system. This measure applies to time of sale opportunities.

### Definition of Baseline Condition

The baseline condition assumes a standard efficiency electric or gas boiler-style steam cooker.

### Definition of Efficient Condition

The efficient condition assumes the installation of an ENERGY STAR qualified electric or gas steam cooker.[808]

### Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = [(1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD}/EFF_i] \times TIME_{idle}$$

$$TIME_{idle} = (HOURS_{DAY} – LB/(PC_i \times PANS))$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + ((1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD}/EFF_i) \times (HOURS_{DAY} – LB/(PC_i \times PANS))] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*[809]

*i* = *either "base" or "eff" depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.*

*$kWh\_Cooking_i$* = *daily cooking energy consumption (kWh).*

*$kWh\_Idle_i$* = *daily idle energy consumption (kWh).*

*$Time_{idle}$* = *daily idle time (h).*

*$kWh_{base}$* = *the annual energy usage of the baseline equipment calculated using baseline values.*

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[808] US EPA. August 2003. ENERGY STAR® Program Requirements Product Specification for Commercial Steam Cookers Eligibility Criteria Version 1.2

[809] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

*$kWh_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values.*

*DAYS = annual days of operation.*

*= if annual days of operation are unknown, assume default of 365 days.*

*LB = Pounds of food cooked per day (lb/day).*

*= if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.*

*$E_{FOOD}$ = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food*

*= 0.0308.*

*EFF = Heavy load cooking energy efficiency (%).*

*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*$PCT_{steam}$ = percent of time in constant steam mode (%).*

*= if percent of time in constant steam mode is unknown, assume default of 40%.*

*IDLE = Idle energy rate (kW).*

*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*PC = Production capacity per pan (lb/hr).*

*= default baseline production capacity per pan is 23.3. If actual efficient production capacity per pan is unknown, assume default of 16.7.*

*PANS = number of pans per unit.*

*= actual installed number of pans per unit.*

*$HOURS_{DAY}$ = average daily operating hours.*

*= if average daily operating hours are unknown, assume default of 12 hours/day.*

**Electric Steam Cooker Performance Metrics: Baseline and Efficient Values**

| Parameter | No. of Pans | Baseline Model | | Energy Efficient Model |
|---|---|---|---|---|
| | | Steam Generator | Boiler Based | All |
| IDLE (kW) | 3 | 1.200 | 1.000 | 0.400 |
| | 4 | | | 0.530 |
| | 5 | | | 0.670 |
| | 6+ | | | 0.800 |
| EFF | All | 30% | 26% | 50% |

### Summer Coincident Peak kW Savings Algorithm [810]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

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[810] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

**Annual Fossil Fuel Savings Algorithm**

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$

$$MMBTU\_Idle_i = [(1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD} /EFF_i] \times TIME_{idle}$$

$$TIME_{idle} = (HOURS_{DAY} – LB/(PC_i \times PANS))$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + ((1 - PCT_{steam}) \times IDLE_i + PCT_{steam} \times PC_i \times PANS \times E_{FOOD} /EFF_i) \times (HOURS_{DAY} – LB/(PC_i \times PANS))] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

*Where:*[811]

$MMBTU_{base}$ = *the annual energy usage of the baseline equipment calculated using baseline values.*

$MMBTU_{eff}$ = *the annual energy usage of the efficient equipment calculated using efficient values.*

$MMBTU\_Cooking_i$ = *daily cooking energy consumption (MMBTU).*

$MMBTU\_Idle_i$ = *daily idle energy consumption (MMBTU).*

$E_{FOOD}$ = *ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food.*
= *0.000105.*

*IDLE* = *Idle energy rate (MMBTU/h).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*PC* = *Production capacity per pan (lb/hr).*
= *default baseline production capacity per pan is 23.3. If actual efficient production capacity per pan is unknown, assume default of 20.*

**Gas Steam Cooker Performance Metrics: Baseline and Efficient Values**

| Parameter | No. of Pans | Baseline Model | | Energy Efficient Model |
|---|---|---|---|---|
| | | Steam Generator | Boiler Based | All |
| IDLE (MMBTU) | 3 | 0.018 | 0.015 | 0.00625 |
| | 4 | | | 0.00835 |
| | 5 | | | 0.01040 |
| | 6+ | | | 0.01250 |
| EFF | All | 18% | 15% | 38% |

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[811] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

### Annual Water Savings Algorithm

$$\Delta Water = (GPH_{base} - GPH_{eff}) \times HOURS_{DAY} \times DAYS.$$

*Where:*[812]

$GPH_{base}$ = *Water consumption rate (gal/h) of baseline equipment.*
*= if water consumption rate of baseline equipment is unknown, assume default values from table below.*

$GPH_{eff}$ = *Water consumption rate (gal/h) of efficient equipment.*
*= if water consumption rate of efficient equipment is unknown, assume default values from table below.*

| | | **Baseline Model** | **Energy Efficient Model** | | |
|---|---|---|---|---|---|
| **Parameter** | **No. of Pans** | **All** | **Steam Generator** | **Boiler Based** | **Boilerless** |
| GPH | All | 40 | 15 | 10 | 3 |

### Measure Life

12 years[813]

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[812] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[813] Ibid.

# Commercial Hot Food Holding Cabinets

**Unique Measure Code(s): CI_KE_TOS_HFHC_0615**
**Effective Date: June 2015**
**End Date: TBD**

### Measure Description

Commercial insulated hot food holding cabinet models that meet ENERGY STAR requirements incorporate better insulation, reducing heat loss, and may also offer additional energy saving devices such as magnetic door gaskets, auto-door closures, or dutch doors. The insulation of the cabinet also offers better temperature uniformity within the cabinet from top to bottom. This means that qualified hot food holding cabinets are more efficient at maintaining food temperature while using less energy. This measure applies to time of sale opportunities.

### Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency hot food holding cabinet.

### Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified hot food holding cabinet.[814]

### Annual Energy Savings Algorithm

$$\Delta kWh = (IDLE_{base} - IDLE_{eff}) / 1000 \times HOURS_{DAY} \times DAYS$$

*Where:*[815]

$IDLE_{base}$ = *the idle energy rate of the baseline equipment (W). See table below for calculation of default values.*

$IDLE_{eff}$ = *the idle energy rate of the efficient equipment (W). If actual efficient values are unknown, assume default values from table below.*

*1,000* = *conversion of W to kW.*

$HOURS_{DAY}$ = *average daily operating hours.*
= *if average daily operating hours are unknown, assume default of 15 hours/day.*

*DAYS* = *annual days of operation.*
= *if annual days of operation are unknown, assume default of 365 days.*

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[814] US EPA. April 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Hot Food Holding Cabinets Eligibility Criteria Version 2.0.

[815] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

### Summary Coincident Peak kW Savings Algorithm [816]

$$\Delta kW = (IDLE_{base} - IDLE_{eff}) / 1000$$

**Hot Food Holding Cabinet Performance Metrics: Baseline and Efficient Values**

| VOLUME (Cubic Feet) | Product Idle Energy Consumption Rate (Watts) | |
|---|---|---|
| | Baseline Model ($IDLE_{base}$) | Efficient Model ($IDLE_{eff}$) |
| 0 < VOLUME < 13 | 40 x VOLUME | 21.5 x VOLUME |
| 13 ≤ VOLUME < 28 | 40 x VOLUME | 2.0 x VOLUME + 254.0 |
| 28 ≤ VOLUME | 40 x VOLUME | 3.8 x VOLUME + 203.5 |

*Note: VOLUME = the internal volume of the holding cabinet (ft$^3$).*
*= actual volume of installed unit*

### Annual Fossil Fuel Savings Algorithm

n/a

### Annual Water Savings Algorithm

n/a

### Measure Life

12 years[817]

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[816] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

[817] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

# Commercial Griddles

**Unique Measure Code(s): CI_KE_TOS_GRID_0615**
**Effective Date: June 2015**
**End Date: TBD**

## Measure Description

ENERGY STAR qualified commercial griddles have higher cooking energy efficiency and lower idle energy rates than standard equipment. The result is more energy being absorbed by the food compared with the total energy use, and less wasted energy when the griddle is in standby mode. This measure applies to time of sale opportunities.

## Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency electric griddle with a cooking energy efficiency of 65% or a gas griddle with a cooking efficiency of 32%.

## Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR qualified electric or gas griddle.[818]

## Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times SIZE \times [HOURS_{DAY} – LB/(PC_i \times SIZE)]$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times SIZE \times (HOURS_{DAY} – LB/(PC_i \times SIZE))] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*[819]

*$i$ = either “base” or “eff” depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.*
*$kWh\_Cooking_i$ = daily cooking energy consumption (kWh).*
*$kWh\_Idle_i$ = daily idle energy consumption (kWh).*
*$kWh_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values.*
*$kWh_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values.*

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[818] US EPA. January 2011. ENERGY STAR® Program Requirements Product Specification for Commercial Griddles Eligibility Criteria Version 1.2.

[819] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

*LB* = *Pounds of food cooked per day (lb/day) .*
= *if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.*

$E_{FOOD}$ = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food.*
= *0.139.*

*EFF* = *Heavy load cooking energy efficiency (%).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*IDLE* = *Idle energy rate (kW/ft²).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*SIZE* = *size of the griddle surface (ft²).*

$HOURS_{DAY}$ = *average daily operating hours.*
= *if average daily operating hours are unknown, assume default of 12 hours/day.*

*PC* = *Production capacity (lb/hr/ft²).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*DAYS* = *annual days of operation.*
= *if annual days of operation are unknown, assume default of 365 days.*

**Efficient Griddle Performance Metrics: Baseline and Efficient Values**

| Parameter | Baseline Model | Efficient Model |
|---|---|---|
| IDLE (kW/ft²) | 0.40 | 0.32 |
| EFF | 65% | 70% |
| PC | 5.83 | 6.67 |

### Summary Coincident Peak kW Savings Algorithm [820]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

### Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$

$$MMBTU\_Idle_i = IDLE_i \times SIZE \times [HOURS_{DAY} – LB/(PC_i \times SIZE)]$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times SIZE \times (HOURS_{DAY} – LB/(PC_i \times SIZE))] \times DAYS$$

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[820] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$

*Where:*[821]

$MMBTU\_Cooking_i$ = *daily cooking energy consumption (MMBTU).*

$MMBTU\_Idle_i$ = *daily idle energy consumption (MMBTU).*

$MMBTU_{base}$ = *the annual energy usage of the baseline equipment calculated using baseline values.*

$MMBTU_{eff}$ = *the annual energy usage of the efficient equipment calculated using efficient values.*

$E_{FOOD}$ = *ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food.*
= *0.000475.*

*IDLE* = *Idle energy rate (MMBTU/h/ft$^2$).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

**Gas Griddle Performance Metrics: Baseline and Efficient Values**

| Parameter | Baseline Model | Efficient Model |
|---|---|---|
| IDLE (MMBTU/h/ft$^2$) | 0.00350 | 0.00265 |
| EFF | 32% | 38% |
| PC | 4.17 | 7.50 |

### Annual Water Savings Algorithm

n/a

### Measure Life

12 years[822]

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[821] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[822] Ibid.

# Commercial Convection Ovens

**Unique Measure Code(s): CI_KE_TOS_CONOV_0619**
**Effective Date: June 2019**
**End Date: TBD**

## Measure Description

Commercial convection ovens that are ENERGY STAR certified have higher heavy load cooking efficiencies and lower idle energy rates making them on average about 20 percent more efficient than standard models. This measure applies to time of sale opportunities.

## Definition of Baseline Condition

The baseline equipment is assumed to be a standard efficiency convection oven with a heavy load efficiency of 65% for full size (i.e., a convection oven this is capable of accommodating full-size sheet pans measuring 18 x 26 x 1-inch) electric ovens, 68% for half size (i.e., a convection oven that is capable of accommodating half-size sheet pans measuring 18 x 13 x 1-inch) electric ovens, and 30% for gas ovens.

## Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR Version 2.2 qualified electric or gas convection oven.[823]

## Annual Energy Savings Algorithm

$$kWh_i = (kWh\_Cooking_i + kWh\_Idle_i) \times DAYS$$

$$kWh\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$kWh\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$kWh_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*[824]

*$i$ = either "base" or "eff" depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.*
*$kWh\_Cooking_i$ = daily cooking energy consumption (kWh).*
*$kWh\_Idle_i$ = daily idle energy consumption (kWh).*

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[823] US EPA. October 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2

[824] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

$kWh_{base}$ = *the annual energy usage of the baseline equipment calculated using baseline values.*

$kWh_{eff}$ = *the annual energy usage of the efficient equipment calculated using efficient values.*

$HOURS_{DAY}$ = *average daily operating hours.*
= *if average daily operating hours are unknown, use default values from Oven Operation by Building Type below*

*DAYS* = *annual days of operation.*
= *if annual days of operation are unknown, use default values from Oven Operation by Building Type below*

$E_{FOOD}$ = *ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food*
= *0.0732.*

*LB* = *Pounds of food cooked per day (lb/day).*
= *if average pounds of food cooked per day is unknown, assume default of 100 lbs/day.*

*EFF* = *Heavy load cooking energy efficiency (%).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*IDLE* = *Idle energy rate (kW).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*PC* = *Production capacity (lb/hr).*
= *see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

**Oven Operation by Building Type**[825]

| Facility Type | hours/day | days/year |
|---|---|---|
| Community College | 11 | 283 |
| Fast Food Restaurant | 14 | 363 |
| Full Service Restaurant | 12 | 321 |
| Grocery | 12 | 365 |
| Hospital | 11 | 365 |
| Hotel | 20 | 365 |
| Miscellaneous | 9 | 325 |
| Motel | 20 | 365 |
| Primary School | 5 | 180 |
| Secondary School | 8 | 180 |
| Office | 12 | 250 |
| University | 11 | 283 |

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[825] California Energy Commission, Characterizing the Energy Efficiency Potential of Gas-Fired Commercial Foodservice Equipment, Appendix E

**Electric Convection Oven Performance Metrics: Baseline and Efficient Values**[826]

| Parameter | Half Size | | Full Size | |
|---|---|---|---|---|
| | Baseline Model | Energy Efficient Model | Baseline Model | Energy Efficient Model |
| IDLE (kW) | 1.03 | 1.00 | 2.00 | 1.60 |
| EFF | 68% | 71% | 65% | 71% |
| PC | 45 | 50 | 90 | 90 |

### Summer Coincident Peak kW Savings Algorithm [827]

$$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$$

### Annual Fossil Fuel Savings Algorithm

$$MMBTU_i = (MMBTU\_Cooking_i + MMBTU\_Idle_i) \times DAYS$$

$$MMBTU\_Cooking_i = LB \times E_{FOOD}/EFF_i$$
$$MMBTU\_Idle_i = IDLE_i \times (HOURS_{DAY} - LB/PC_i)$$

$$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} - LB/PC_i)] \times DAYS$$

$$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$$

*Where:*[828]

*$MMBTU\_Cooking_i$ = daily cooking energy consumption (MMBTU).*
*$MMBTU\_Idle_i$ = daily idle energy consumption (MMBTU).*
*$MMBTU_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values.*
*$MMBTU_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values.*
*$E_{FOOD}$ = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during cooking, per pound of food.*
*= 0.000250.*
*IDLE = Idle energy rate (MMBTU/h).*
*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

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[826] Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php.

[827] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

[828] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

**Gas Convection Oven Performance Metrics: Baseline and Efficient Values**

| Parameter | Baseline Model | Energy Efficient Model |
|---|---|---|
| IDLE (MMBTU/h) | 0.0151 | 0.0120 |
| EFF | 44% | 46% |
| PC | 83 | 86 |

### Annual Water Savings Algorithm

n/a

### Measure Life

12 years[829]

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[829] US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

# Commercial Combination Ovens

**Unique Measure Code(s): CI_KE_TOS_COMOV_0619**
**Effective Date: June 2019**
**End Date: TBD**

### Measure Description

A combination oven is a convection oven that includes the added capability to inject steam into the oven cavity and typically offers at least three distinct cooking modes. This measure applies to time of sale opportunities.

### Definition of Baseline Condition

The baseline equipment is assumed to be a typical standard efficiency electric or gas combination oven.

### Definition of Efficient Condition

The efficient equipment is assumed to be an ENERGY STAR Version 2.2 qualified electric or gas combination oven.[830]

### Annual Energy Savings Algorithm

$$kWh_{i,j} = (kWh\_Cooking_{i,j} + kWh\_Idle_{i,j}) \times DAYS$$

$$kWh\_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$$
$$kWh\_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} – LB/PC_{i,j}) \times PCT_j$$

$$kWh_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} – LB/PC_{i,j})] \times PCT_j \times DAYS$$

$$kWh_{base} = kWh_{base,conv} + kWh_{base,steam}$$
$$kWh_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$$

$$\Delta kWh = kWh_{base} - kWh_{eff}$$

*Where:*[831]

*i* = *either "base" or "eff" depending on whether the calculation of energy consumption is being performed for the baseline or efficient case, respectively.*
*j* = *cooking mode; either "conv" (i.e., convection) or "steam".*
$kWh\_Cooking_{i,j}$ = *daily cooking energy consumption (kWh).*
$kWh\_Idle_{i,j}$ = *daily idle energy consumption (kWh).*

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[830] US EPA. October 2015. ENERGY STAR® Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2

[831] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

*$kWh_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values.*

*$kWh_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values.*

*$HOURS_{DAY}$ = average daily operating hours.*
*= if average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in "Commercial Convection Ovens"*

*DAYS = annual days of operation.*
*= if annual days of operation are unknown, refer to the default values from Oven Operation by Building Type in "Commercial Convection Ovens".*

*$E_{FOOD,conv}$ = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during convention mode cooking, per pound of food.*
*= 0.0732.*

*$E_{FOOD,steam}$ = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during steam mode cooking, per pound of food.*
*= 0.0308.*

*LB = Pounds of food cooked per day (lb/day).*
*= if average pounds of food cooked per day is unknown, assume default of 200 lbs/day.*

*EFF = Heavy load cooking energy efficiency (%).*
*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*IDLE = Idle energy rate (kW).*
*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*PC = Production capacity (lb/hr).*
*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

*$PCT_j$ = percent of food cooked in cooking mode j. Note: $PCT_{conv}$ + $PCT_{steam}$ must equal 100%.*
*= if percent of food cooked in cooking mode j is unknown, assume default of $PCT_{conv}$ = $PCT_{steam}$ = 50%.*

**Electric Combination Oven Performance Metrics: Baseline and Efficient Values**

| Parameter | No. of Pans | Baseline Model | | Energy Efficient Model | |
|---|---|---|---|---|---|
| | | **Convection Mode** | **Steam Mode** | **Convection Mode** | **Steam Mode** |
| IDLE (kW) | < 15 | 1.320 | 5.260 | 0.08 x PANS + 0.4989 | 0.133 x PANS + 0.64 |
| | >= 15 | 2.280 | 8.710 | | |
| EFF | All | 72% | 49% | 76% | 55% |
| PC | < 15 | 79 | 126 | 119 | 177 |
| | >= 15 | 166 | 295 | 201 | 349 |

*Note: PANS = The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.*

**Summer Coincident Peak kW Savings Algorithm** [832]

$\Delta kW = \Delta kWh / (HOURS_{DAY} \times DAYS)$

**Annual Fossil Fuel Savings**

$MMBTU_i = [LB \times E_{FOOD}/EFF_i + IDLE_i \times (HOURS_{DAY} – LB/PC_{i)}] \times DAYS$

$MMBTU\_Cooking_{i,j} = LB \times E_{FOOD,j}/EFF_{i,j} \times PCT_j$
$MMBTU\_Idle_{i,j} = IDLE_{i,j} \times (HOURS_{DAY} – LB/PC_{i,j}) \times PCT_j$

$MMBTU_{i,j} = [LB \times E_{FOOD,j}/EFF_{i,j} + IDLE_{i,j} \times (HOURS_{DAY} – LB/PC_{i,j})] \times PCT_j \times DAYS$

$MMBTU_{base} = kWh_{base,conv} + kWh_{base,steam}$
$MMBTU_{eff} = kWh_{eff,conv} + kWh_{eff,steam}$

$\Delta MMBTU = MMBTU_{base} - MMBTU_{eff}$

*Where:*[833]

*$MMBTU\_Cooking_i$ = daily cooking energy consumption (MMBTU).*
*$MMBTU\_Idle_i$ = daily idle energy consumption (MMBTU).*
*$MMBTU_{base}$ = the annual energy usage of the baseline equipment calculated using baseline values.*
*$MMBTU_{eff}$ = the annual energy usage of the efficient equipment calculated using efficient values.*
*$E_{FOOD,conv}$ = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during convention mode cooking, per pound of food.*
*= 0.000250.*
*$E_{FOOD,steam}$ = ASTM Energy to Food (MMBTU/lb); the amount of energy absorbed by the food during steam mode cooking, per pound of food.*
*= 0.000105.*
*LB = Pounds of food cooked per day (lb/day).*
*= if average pounds of food cooked per day is unknown, assume default of 250 lbs/day.*
*IDLE = Idle energy rate (MMBTU/h).*

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[832] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

[833] Unless otherwise noted, all default assumption from US EPA. February 2015. Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

*= see table below for default baseline values. If actual efficient values are unknown, assume default values from table below.*

**Gas Combination Oven Performance Metrics: Baseline and Efficient Values**

| Parameter | No. of Pans | Baseline Model | | Energy Efficient Model | |
|---|---|---|---|---|---|
| | | Convection Mode | Steam Mode | Convection Mode | Steam Mode |
| IDLE (MMBTU/h) | < 15 | 0.008747 | 0.018656 | 0.000150 x PANS + 0.005425 | 0.000200 x PANS + 0.006511 |
| | >= 15 and < 30 | 0.007823 | 0.024562 | | |
| | >= 30 | 0.013000 | 0.043300 | | |
| EFF | All | 52% | 39% | 56% | 41% |
| PC | < 15 | 125 | 195 | 124 | 172 |
| | >= 15 and < 30 | 176 | 211 | 210 | 277 |
| | >= 30 | 392 | 579 | 394 | 640 |

*Note: PANS = The number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification.*

**Annual Water Savings Algorithm**

n/a

**Measure Life**

12 years[834]

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[834] Ibid.

# ENERGY STAR Commercial Rack Oven

**Unique Measure Code(s): CI_KE_TOS_RACKOV_0619**
**Effective Date: June, 2019**
**End Date: TBD**

## Measure Description

This measure describes a time of sale or new construction installation of an ENERGY STAR qualified, single or double gas rack oven. These large commercial ovens are frequently used in high volume backing facilities and other food service operations, such as supermarkets, high volume bakeries, and institutions.

## Definition of Baseline Condition

The baseline condition is a standard efficiency gas rack oven.

## Definition of Efficient Condition

The efficient condition is a high-efficiency gas rack oven meeting ENERGY STAR Version 2.2 requirements[835].

## Annual Energy Savings Algorithm

n/a

## Summer Coincident Peak kW Savings Algorithm

n/a

## Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = DAYS * (\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}) / 1{,}000{,}000$$

$$\Delta BTU_{preheat} = N_{preheat} * (BTU_{preheat,baseline} - BTU_{preheat,ee})$$

$$\Delta BTU_{idle} = (BTU/h_{idle,baseline} - * BTU/h_{idle,ee}) * (HOURS_{day} - N_{preheat} * hrs_{preheat} - (LB / PC))$$

$$\Delta BTU_{cooking} = LB * E_{food} * (1/Eff_{baseline} - 1/Eff_{ee})$$

*Where:*

*DAYS* = annual days of operation.
= If annual days of operation are unknown, refer to the default values from Oven Operation by Building Type in “Commercial Convection Ovens”.
*$HOURS_{day}$* = average daily operating hours.

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[835] ENERGY STAR Program Requirements Product Specification for Commercial Ovens Eligibility Criteria Version 2.2, ENERGY STAR, October 2015.

= If average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in “Commercial Convection Ovens”.

$N_{preheat}$ = Number of preheats per day. If unknown use 1[836] preheat per day.

$hrs_{preheat}$= Preheat duration (hrs). Assume 0.33[837] if unknown.

$BTU_{preheat,base}$ = Equipment preheat energy (BTU). Use default values in Default Assumptions for Rack Ovens below.

$BTU_{preheat,ee}$ = Equipment preheat energy (BTU). Use default values in Default Assumptions for Rack Ovens below if unknown.

$BTU/h_{idle,base}$ = Equipment idle energy rate (BTU/h). Use default values in Default Assumptions for Rack Ovens table below.

$BTU/h_{idle,ee}$ = Equipment idle energy rate (BTU/h). Use default values in Default Assumptions for Rack Ovens table below if unknown.

$LB$ = Pounds of food cooked per day (lb/day). Use default values in Default Assumptions for Rack Ovens table below if unknown.

$PC$ = Production capacity (lb/hr). Use default values in Default Assumptions for Rack Ovens table below if unknown.

$E_{food}$ = ASTM Energy to Food (Btu/lb); the amount of energy absorbed by the food during cooking, per pound of food. Assume 235[838] if unknown.

$Eff_{base}$ = Equipment convection/steam mode cooking efficiency (%). Use 30%[839] if unknown.

$Eff_{base}$ = Equipment convection/steam mode cooking efficiency (%). Use default values for $Eff_{ee}$ in Oven Operation by Building Type table below if unknown.

**Default Assumptions for Rack Ovens**[840]

| Variable | Rack Oven, Gas, Double Rack | Rack Oven, Gas, Single Rack |
|---|---|---|
| LB | 1,200 | 600 |
| $BTU_{preheat,baseline}$ | 100,000 | 50,000 |
| $BTU_{preheat,ee}$ | 85,000 | 44,000 |
| $BTU/h_{idle,baseline}$ | 65,000 | 43,000 |
| $BTU/h_{idle,ee}$ | 30,000 | 25,000 |
| PC | 250 | 130 |
| $Eff_{ee}$ | 52% | 48% |

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[836] PG&E Work Paper PGECOFST109 Revision 5, Table 12, pg. 7, Download from http://deeresources.net/workpapers

[837] Ibid.

[838] Ibid.

[839] Ibid.

## Annual Water Savings Algorithm

n/a

## Measure Life

12 years[841]

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[841] Food Service Technology Center: Gas Rack Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-rack-ovens/#calc

# Commercial Conveyor Oven

**Unique Measure Code(s): CI_KE_TOS_RACKOV_0619**
**Effective Date: June, 2019**
**End Date: TBD**

## Measure Description

This measure describes a time of sale or new construction installation of a high-efficiency gas-fired conveyor oven. Conveyor ovens are used in the large-scale production of various food service operations and are used extensively for pizza production.

## Definition of Baseline Condition

The baseline condition is a standard efficiency gas conveyor with an efficiency of 20%, a preheat energy of 35,000, an idle energy rate of 70,000 BTU/h, and a production capacity (PC) of 114 lbs/hr.

## Definition of Efficient Condition

The efficient condition is a high-efficiency gas rack oven meeting minimum requirements of qualified conveyor ovens by the Food Service Technology Center (FSTC). Minimum requirements are shown below, in “Minimum Conveyor Oven Requirements”.

**Minimum Conveyor Oven Requirements**

| | |
|---|---|
| $BTU_{preheat}$ | 18,000 |
| $BTU/h_{idle}$ | 57,000 |
| Eff | 42% |
| PC | 167 |

## Annual Energy Savings Algorithm

n/a

## Summer Coincident Peak kW Savings Algorithm

n/a

## Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = DAYS * (\Delta BTU_{preheat} + \Delta BTU_{idle} + \Delta BTU_{cooking}) / 1{,}000{,}000$$

$$\Delta BTU_{preheat} = N_{preheat} * (BTU_{preheat,baseline} - BTU_{preheat,ee})$$

$$\Delta BTU_{idle} = (BTU/h_{idle,baseline} - * BTU/h_{idle,ee}) * (HOURS_{day} - N_{preheat} * hrs_{preheat} - (LB / PC))$$

$$\Delta BTU_{cooking} = LB * E_{food} * (1/Eff_{baseline} - 1/Eff_{ee})$$

*Where:*

$DAYS$ = annual days of operation. If unknown, refer to the default values from Oven Operation by Building Type found in the "Commercial Convection Oven" measure.

$HOURS_{day}$ = average daily operating hours.
= If average daily operating hours are unknown, refer to the default values from Oven Operation by Building Type in the "Commercial Convection Oven" measure .

$N_{preheat}$ = Number of preheats per day. If unknown use 1[842] preheat per day.

$hrs_{preheat}$= Preheat duration (hrs). Assume 0.25[843] if unknown.

$BTU_{preheat,base}$ = Equipment preheat energy (BTU). Use 35,000[844] by default.

$BTU_{preheat,ee}$ = Actual equipment preheat energy (BTU).

$BTU/h_{idle,base}$ = Equipment idle energy rate (BTU/h). Use 70,000[845] by default.

$BTU/h_{idle,ee}$ = Actual equipment idle energy rate (BTU/hr).

$LB$ = Pounds of food cooked per day (lb/day). Use 190[846] if unknown.

$PC_{baseline}$ = Production capacity (lb/hr). Use 114[847] if unknown.

$PC_{ee}$ = Actual production capacity (lb/hr)..

$E_{food}$ = ASTM Energy to Food (Btu/lb); the amount of energy absorbed by the food during cooking, per pound of food. Assume 250[848] if unknown.

$Eff_{baseline}$ = Equipment convection/steam mode cooking efficiency (%). Use 20%[849] if unknown.

$Eff_{ee}$ = Actual equipment convection/steam mode cooking efficiency (%).

**Annual Water Savings Algorithm**

n/a

**Measure Life**

12 years[850]

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[842] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, Download from http://deeresources.net/workpapers

[843] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6 - Download from http://deeresources.net/workpapers

[844] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

[845] Ibid.

[846] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, where 1 pizza equals 0.76 lbs - Download from http://deeresources.net/workpapers

[847] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, where 1 pizza equals 0.76 lbs, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

[848] PG&E Work Paper PGECOFST117 Revision 5, Table 9, pg. 5-6, where 1 pizza equals 0.76 lbs - Download from http://deeresources.net/workpapers

[849] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

[850] Food Service Technology Center: Gas Conveyor Oven Life-Cycle Cost Calculator, https://caenergywise.com/calculators/natural-gas-conveyor-ovens/#calc

# Commercial Ice Makers

**Unique Measure Code(s): CI_KE_TOS_ICE_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency automatic commercial ice maker which are used in restaurants, bars, hotels, hospitals and a variety of commercial and industrial facilities for both food and patient care applications.

### Definition of Baseline Condition

This is defined as a time of sale measure. The baseline condition is a standard-efficiency automatic commercial ice maker meeting, but not exceeding, federal energy efficiency standards.

**Definition of Efficient Condition** The efficient condition is a high-efficiency automatic commercial ice maker meeting ENERGY STAR Version 3.0 requirements.

### Annual Energy Savings Algorithm

$\Delta kWh = (ECR_{base} - ECR_{EE})/100 \times DAYS \times DUTY \times H$

*Where:*

$ECR_{base}$ = *the energy consumption rate of the baseline (kWh/100 lb ice). This value is calculated from the tables below using ice harvest rate.*

$ECR_{EE}$ = *the energy consumption rate of the efficient equipment (kWh/100 lb ice). This value is calculated from the tables below using ice harvest rate.*

*DAYS* = *annual days of operation.*

= *if annual days of operation are unknown, assume default of 365 days.*

*DUTY* = *duty cycle of ice maker.*

= *0.40*[851]

*H* = *harvest rate (lb ice/24 hours) of the efficient equipment.*

| Batch Type Commercial Ice Makers | | | |
|---|---|---|---|
| **Equipment type** | **Harvest rate (lb ice/24 hours)** | **Federal Baseline Maximum Energy Consumption Rate (kWh/100 lb ice)[852]** | **ENERGY STAR Maximum Energy Consumption Rate (kWh/100 lb ice)[853]** |
| Ice-Making Head | < 300 | 10-0.01233*H | 9.20 - 0.01134*H |
| Ice-Making Head | ≥ 300 and < 800 | 7.05-0.0025*H | 6.49 - 0.0023*H |
| Ice-Making Head | ≥ 800 and < 1,500 | 5.55-0.00063*H | 5.11 - 0.00058*H |
| Ice-Making Head | ≥ 1500 and < 4,000 | 4.61 | 4.24 |
| Remote Condensing (but not remote compressor) | < 988 | 7.97-0.00342*H | 7.17 – 0.00308*H |
| Remote Condensing (but not remote compressor) | ≥ 988 and < 4,000 | 4.59 | 4.13 |
| Remote Condensing and Remote Compressor | < 930 | 7.97-0.00342*H | 7.17 – 0.00308*H |
| Remote Condensing and Remote Compressor | ≥ 930 and < 4,000 | 4.79 | 4.13 |
| Self-Contained | < 110 | 14.79-0.0469*H | 12.57 - 0.0399*H |
| Self-Contained | ≥ 110 and < 200 | 12.42-0.02533*H | 10.56 – 0.0215*H |

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[851] Duty cycle varies considerably from one installation to the next. TRM assumptions from Vermont, Wisconsin, and New York vary from 40 to 57%, whereas the ENERGY STAR Commercial Ice Machine Savings Calculator <http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Ice_Machines.xls> assumes a value of 75%. A field study of eight ice machines in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007). Furthermore, a report prepared by ACEEE assumed a value of 40% (Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002). For conservatism, this characterization assumed a value of 40%.

[852] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53

[853] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

| | | | |
|---|---|---|---|
| Self-Contained | ≥ 200 and < 4,000 | 7.35 | 6.25 |

| Continuous Type Commercial Ice Makers | | | |
|---|---|---|---|
| **Equipment type** | **Harvest rate (lb ice/24 hours)** | **Federal Baseline Maximum Energy Consumption Rate (kWh/100 lb ice)[854]** | **ENERGY STAR Maximum Energy Consumption Rate (kWh/100 lb ice)[855]** |
| Ice-Making Head | <310 | 9.19-0.00629*H | 7.90 – 0.005409*H |
| Ice-Making Head | ≥310 and <820 | 8.23-0.0032*H | 7.08 – 0.002752*H |
| Ice-Making Head | ≥820 and <4,000 | 5.61 | 4.82 |
| Remote Condensing (but not remote compressor) | <800 | 9.7-0.0058*H | 7.76 – 0.00464*H |
| Remote Condensing (but not remote compressor) | ≥800 and <4,000 | 5.06 | 4.05 |
| Remote Condensing and Remote Compressor | <800 | 9.9-0.0058*H | 7.76 – 0.00464*H |
| Remote Condensing and Remote Compressor | ≥800 and <4,000 | 5.26 | 4.05 |
| Self-Contained | <200 | 14.22-0.03*H | 12.37 – 0.0261*H |
| Self-Contained | ≥200 and <700 | 9.47-0.00624*H | 8.24 – 0.005429*H |
| Self-Contained | ≥700 and <4,000 | 5.1 | 4.44 |

### Summary Coincident Peak kW Savings Algorithm [856]

$$\Delta kW = (ECR_{base} - ECR_{EE})/2,400 \times H \times CF$$

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[854] https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=53

[855] https://www.energystar.gov/products/commercial_food_service_equipment/commercial_ice_makers/key_product_criteria

[856] No specific study of commercial kitchen equipment coincident peak demand savings is available. In the absence of this information, a simple average demand value is used: Annual energy savings divided by the total annual hours of operation.

*Where:*

*CF = Summer Peak Coincident Factor for measure*
*= 0.772* [857]

### Annual Fossil Fuel Savings Algorithm

n/a

### Water Savings Algorithm[858]

The water savings associated with this measure vary depending on the configuration of the ice machine and are listed in the table below.

| **Ice Maker Type** | **Annual Water Savings (gal/unit)** |
|---|---|
| Ice Making Head | 3,322 |
| Self-Contained Unit | 3,526 |
| Remote Condensing Unit (Batch) | 2,631 |
| Remote Condensing Unit (Continuous) | 0 |

### Measure Life

8 years[859]

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[857] Assumes that the summer peak coincidence factor for commercial ice machines is consistent with that of general commercial refrigeration equipment. Characterization assumes a value of 77.2% adopted from the Efficiency Vermont Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions, March, 16, 2015, until a region specific study is conducted.

[858] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[859] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

# Commercial Dishwashers

**Unique Measure Code(s): CI_KE_TOS_DISH_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure describes the installation of an ENERGY STAR qualified, high-efficiency stationary and conveyor-type commercial dishwashers used in commercial kitchen establishments that use non-disposable dishes, glassware, and utensils. Commercial dishwashers can clean and sanitize a large quantity of kitchenware in a short amount of time by utilizing hot water, soap, rinse chemicals, and significant amounts of energy. Energy Star qualified models use less water and have lower idling rates than non-Energy Star rated models.

The savings derived below are heavily dependent on the assumed dishwasher hours of operation, which are consistent with a high usage restaurant or cafeteria operation. If dishwashers are found to be installed in applications with significantly different hours of operation, the hours and savings shall be revised in a custom calculation.

This measure is not applicable to flight machines, which are continuous conveyor machines built specifically for large institutions.

### Definition of Baseline Condition

This is defined as a time of sale measure. The baseline condition is a standard non-ENERGY STAR commercial dishwasher.[860]

### Definition of Efficient Condition

The efficient condition is a high-efficiency commercial dishwasher meeting ENERGY STAR Version 2.0 requirements.[861]

### Annual Energy Savings Algorithm

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

*Where:*

$kWh_{BASE}$ = *Baseline kWh consumption per year*
= *Values provided in tables below.*
$kWh_{EFF}$ = *ENERGY STAR kWh consumption per year*
= *Values provided in tables below.*

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[860] The baseline condition is based on the assumptions used for the conventional commercial dishwashers in the ENERGY STAR Savings Calculator for Certified Commercial Kitchen Equipment. http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx.

[861] ENERGY STAR Program Requirements for Commercial Dishwashers Version 2.0, ENERGY STAR, February 2013.

| **Commercial Dishwasher Annual Energy Use (kWh)[862]** | | | | |
|---|---|---|---|---|
| *Building hot water fuel type / Booster water heater fuel type* | **Electric / Electric** | | **Electric / Natural Gas** | |
| | **Baseline** | **ENERGY STAR** | **Baseline** | **ENERGY STAR** |
| **Low Temperature** | | | | |
| Under Counter | 9,403 | 7,225 | 9,403 | 7,225 |
| Stationary Single Tank Door | 33,683 | 19,832 | 33,683 | 19,832 |
| Single Tank Conveyor | 36,189 | 24,504 | 36,189 | 24,504 |
| Multi Tank Conveyor | 42,943 | 26,812 | 42,943 | 26,812 |
| **High Temperature** | | | | |
| Under Counter | 10,595 | 7,876 | 8,083 | 5,894 |
| Stationary Single Tank Door | 34,151 | 23,978 | 23,053 | 16,321 |
| Single Tank Conveyor | 39,070 | 31,171 | 28,378 | 22,568 |
| Multi Tank Conveyor | 62,148 | 38,645 | 44,265 | 28,690 |
| Pot, Pan, and Utensil | 18,064 | 15,225 | 12,041 | 10,235 |

| **Commercial Dishwasher Annual Energy Use (kWh)[863]** | | | | |
|---|---|---|---|---|
| *Building hot water fuel type / Booster water heater fuel type* | **Natural Gas / Natural Gas** | | **Natural Gas / Electric** | |
| | **Baseline** | **ENERGY STAR** | **Baseline** | **ENERGY STAR** |
| **Low Temperature** | | | | |
| Under Counter | 2,426 | 2,426 | 2,426 | 2,426 |
| Stationary Single Tank Door | 2,066 | 2,066 | 2,066 | 2,066 |
| Single Tank Conveyor | 8,013 | 7,512 | 8,013 | 7,512 |
| Multi Tank Conveyor | 9,390 | 9,390 | 9,390 | 9,390 |
| **High Temperature** | | | | |
| Under Counter | 3,687 | 2,426 | 6,199 | 4,408 |
| Stationary Single Tank Door | 3,631 | 2,921 | 14,729 | 10,578 |
| Single Tank Conveyor | 9,665 | 7,512 | 20,358 | 16,115 |
| Multi Tank Conveyor | 12,971 | 11,268 | 30,853 | 21,223 |
| Pot, Pan, and Utensil | 1,502 | 1,502 | 7,525 | 6,492 |

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[862] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[863] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

**Summer Coincident Peak kW Savings Algorithm**

$\Delta kW = \Delta kWh \times CF / HOURS$

*Where:*

*HOURS = annual operating hours.*
*=5,634*[864]
*CF = Summer Peak Coincident Factor for measure*
*= 0.9*[865]

**Annual Fossil Fuel Savings Algorithm**

$\Delta MMBtu = MMBtu_{BASE} - MMBtu_{EFF}$

*Where:*

*$MMBtu_{BASE}$ = Baseline natural gas consumption per year*
*= Values provided in tables below.*
*$MMBtu_{EFF}$ = ENERGY STAR natural gas consumption per year*
*= Values provided in tables below.*

| Commercial Dishwasher Annual Energy Use (MMBtu)[866] | | | | |
|---|---|---|---|---|
| *Building hot water fuel type / Booster water heater fuel type* | **Electric / Electric** | | **Electric / Natural Gas** | |
| | **Baseline** | **ENERGY STAR** | **Baseline** | **ENERGY STAR** |
| **Low Temperature** | | | | |
| Under Counter | 0.0 | 0.0 | 0.0 | 0.0 |
| Stationary Single Tank Door | 0.0 | 0.0 | 0.0 | 0.0 |
| Single Tank Conveyor | 0.0 | 0.0 | 0.0 | 0.0 |
| Multi Tank Conveyor | 0.0 | 0.0 | 0.0 | 0.0 |
| **High Temperature** | | | | |
| Under Counter | 0.0 | 0.0 | 10.5 | 8.3 |
| Stationary Single Tank Door | 0.0 | 0.0 | 46.4 | 32.0 |
| Single Tank Conveyor | 0.0 | 0.0 | 44.7 | 36.0 |
| Multi Tank Conveyor | 0.0 | 0.0 | 74.8 | 41.6 |
| Pot, Pan, and Utensil | 0.0 | 0.0 | 25.2 | 20.9 |

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[864] The ENERGY STAR default value of 365 days per year seems excessive. 6 day operation is assumed (365 * 6/7) = 313 days/year at 18 hours per day, or 5,634 hours per year. This approach aligns with the MA TRM.

[865] PG&E Work Paper PGECOFST126 Revision 0, Table 10, pg. 18

[866] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation.
<http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

| Commercial Dishwasher Annual Energy Use (MMBtu)[867] | | | | |
|---|---|---|---|---|
| *Building hot water fuel type / Booster water heater fuel type* | **Natural Gas / Natural Gas** | | **Natural Gas / Electric** | |
| | **Baseline** | **ENERGY STAR** | **Baseline** | **ENERGY STAR** |
| **Low Temperature** | | | | |
| Under Counter | 29.2 | 20.1 | 29.2 | 20.1 |
| Stationary Single Tank Door | 132.2 | 74.3 | 132.2 | 74.3 |
| Single Tank Conveyor | 117.8 | 71.0 | 117.8 | 71.0 |
| Multi Tank Conveyor | 140.3 | 72.8 | 140.3 | 72.8 |
| **High Temperature** | | | | |
| Under Counter | 28.9 | 22.8 | 18.4 | 14.5 |
| Stationary Single Tank Door | 127.6 | 88.0 | 81.2 | 56.0 |
| Single Tank Conveyor | 122.9 | 98.9 | 78.2 | 62.9 |
| Multi Tank Conveyor | 205.6 | 114.5 | 130.8 | 72.8 |
| Pot, Pan, and Utensil | 69.2 | 57.4 | 44.1 | 36.5 |

### Annual Water Savings Algorithm

$$\Delta \text{Water (CCF)} = \text{Water}_{BASE} - \text{Water}_{EFF}$$

*Where*

$Water_{BASE}$ = *Annual water consumption of baseline unit.*
= *Values provided in tables below.*
$Water_{EFF}$ = *Annual water consumption of ENERGY STAR unit.*
= *Values provided in tables below.*

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[867] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

| | **Annual Water Consumption (CCF)**[868] | |
|---|---|---|
| | **Baseline** | **ENERGY STAR** |
| ***Low Temperature*** | | |
| Under Counter | 54.3 | 37.3 |
| Stationary Single Tank Door | 246.0 | 138.2 |
| Single Tank Conveyor | 219.3 | 132.2 |
| Multi Tank Conveyor | 261.1 | 135.6 |
| ***High Temperature*** | | |
| Under Counter | 34.2 | 27.0 |
| Stationary Single Tank Door | 151.1 | 104.3 |
| Single Tank Conveyor | 145.6 | 117.2 |
| Multi Tank Conveyor | 243.5 | 135.6 |
| Pot, Pan, and Utensil | 82.0 | 68.0 |

**Measure Life**

The life of a commercial dishwasher varies based on configuration and is listed in the table below.[869]

| **Machine Type** | **Measure Life (years)** |
|---|---|
| Under Counter | 10 |
| Stationary Single Tank Door | 15 |
| Single Tank Conveyor | 20 |
| Multi Tank Conveyor | 20 |
| Pot, Pan, and Utensil | 10 |

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[868] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment based on 5,634 annual hours of operation. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

[869] Savings Calculator for ENERGY STAR Certified Commercial Kitchen Equipment. <http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx>

# Demand Control Commercial Kitchen Ventilation

**Unique Measure Code(s): CI_KE_TOS_DCVENT_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a demand control kitchen ventilation system (DCKV) in a commercial kitchen. DCKV systems employ active cooking sensors to reduce ventilation rates when the full ventilation capacity is not required. Ventilation is reduced by a variable frequency drives in both exhaust fans and make-up air fans. Savings is realized from both direct fan electrical savings as well as less conditioned air being exhausted.

This measure applies to retrofit, time of sale, and new construction.

### Definition of Baseline Condition

Commercial kitchens typically have only a manual on/off switch, whereby the exhaust hoods and make-up air run at full design capacity.

### Definition of Efficient Condition

The efficient system will be capable of at least 50% reduction from the maximum design speed. User controls shall provide a visual indication of a fault in the same room as the unit when the system is bypassed or disabled. Ventilation will be reduced by variable speed drives which are controlled by optical cooking sensors, infrared cooking sensors, temperature-based sensors, and/or direct appliance communication. Optical sensors shall be placed in the hood, infrared sensors shall be directed at cooking equipment, and temperature sensors shall be positioned in the hood or duct.

### Annual Energy Savings Algorithm

If:

$$\Delta kWH = \Delta kWh_{fan} + \Delta kWh_{cooling}$$

$$\Delta kWh_{fan} = \left(\frac{CFM}{1400\text{[870]}}\right) * Hours * \ Days * Weeks * \ \sum_{0\%}^{100\%}(\%FF * PLR)$$

$$\Delta kWh_{cooling} = SF_{Cool} * \%MUA_{Cool} * \Delta kWh_{fan}$$

*Where:*

*CFM* = *Uncontrolled design hood exhaust flow in cubic feet per minute.*
= *If actual flow is unknown, estimate flow from hood dimensions. For unlisted hoods estimate 100 CFM per square foot of plan area. For UL listed hoods estimate 250 CFM per length of hood in feet.*

*Hours* = *Hours per day hood is operated.*
= *If actual hours are unknown, assume 5 hours per meal served.*

*Days* = *Number of days kitchen is in operation per week.*

---

[870] Estimation of CFM delivered per kW consumed from both exhaust and make-up air fan motor. Derived from proprietary Navigant DCKW tool.

*Weeks* = *Number of weeks kitchen is in operation.*

= *If actual weeks are unknown assume 50 weeks per year.*

*%FF* = *Percentage of run-time spent within a given flow fraction range.*

= *If actual values unknown, assume 30% of time at full flow, 30% of time at 75% flow, and 40% of time at 50% flow.*

*PLR* = *Part load ratio for a given flow fraction range.*

= *For Flow Fractions abvoe 50%, PLR = Flow fraction^(2.5). Example: for a flow fraction of 75% the PLR =* $(0.75)^{2.5}$ *= 0.487. Otherwise use PLR table below.*

**Part Load Ratios by Control and Fan Type and Flow Fraction (PLR)**

| Control Type | Flow Fraction | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| VFD | 0.09 | 0.10 | 0.11 | 0.15 | 0.20 | 0.28 | 0.41 | 0.57 | 0.77 | 1.00 |

$SF_{Cool}$ = Cooling savings factor.

= 0.471.[871]

$\%MUA_{Cool}$ = During the cooling season, the percentage of make-up air that is conditioned. If kitchen is cooled, then %CMUA = 1.0. If kitchen is not cooled, then must calculate the percentage of make-up air that is being pulled from the dining room or other conditioned space.

= If actual value is unknown, then assume 30%, or 0.3.

### Summer Coincident Peak kW Savings Algorithm

$$\Delta kW = \Delta kWh/(Hours * Days * Weeks) * CF$$

*Where:*

*CF* = 1.0 if kitchen operates during dinner, 0.0 if the kitchen does not operate during dinner.

### Annual Fossil Fuel Savings Algorithm

$$\Delta MMBTU = SF_{Heat} * \Delta kWh_{fan}$$

*Where:*

$SF_{Heat}$ = Heating savings factor from table below. If percent of make-up air from dining room is unknown, assume 30% from dining room.

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[871] Savings factor calculated from proprietary Navigant DCKW tool using TMY3 temperature data from Baltimore, MD. The tool does a bin hour calculation of the cooling energy required to condition make-up air.

**Heading Savings Factor ($SF_{Heat}$)[872]**

| Percent of Make-up Air from Nearby Conditioned Space (Dining Room) | Make-up Air Directly Supplied to Kitchen is NOT Heated | Make-up Air Directly Supplied to Kitchen is Heated |
|---|---|---|
| 0% | 0 | 0.0088 |
| 10% | 0.0013 | 0.0093 |
| 20% | 0.0026 | 0.0097 |
| 30% | 0.0039 | 0.0101 |
| 40% | 0.0042 | 0.0105 |
| 50% | 0.0065 | 0.0109 |
| 60% | 0.0078 | 0.0113 |
| 70% | 0.0091 | 0.0118 |
| 80% | 0.0104 | 0.0122 |
| 90% | 0.0117 | 0.0126 |
| 100% | 0.0130 | 0.0130 |

### Annual Water Savings Algorithm

n/a

### Measure Life

The measure life is assumed to be 15 years.[873]

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[872] Saving factor calculated from proprietary Navigant DCKW tool using TMY3 temperature data from Baltimore, MD. The tool does a bin hour calculation of the heating energy required to condition make-up air.

[873] DEER lifetime for a VFD controlled by a CO2 sensor. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx See row 81 of the "Updated 2014 EUL table" tab of the workbook.

*Industrial Equipment*

# Variable Speed Drive Screw Air Compressors

**Unique Measure Code(s): CI_KE_TOS_VSDSCRAIR_0420**
**Effective Date: April 2020**
**End Date: TBD**

### Measure Description

This measure relates to the installation of a new high-efficiency oil-flooded, screw air compressor of 100 HP or less with a variable speed drive. Applications above 100 HP should receive custom analysis. This measure applies to time of sale and new construction.

### Definition of Baseline Condition

The baseline condition is a modulating with blow down screw compressor. Baseline compressors choke off the inlet air to modulate the compressor output, resulting in inefficient operation.

### Definition of Efficient Condition

A 100 HP or less screw compressor with variable speed control on the motor to match output to the load.

### Annual Energy Savings Algorithm

$$\Delta kWh = 0.9^{[874]} * HP * HOURS * (COMPF_{base} – COMPF_{ee})$$

*Where:*

*HP* = *Compressor motor nominal HP*
*HOURS* = *Compressor total hours of operation*
= *If unknown, see* “Compressor Total Hours of Operation and Coincidence Factor, if unknown“ below.
*$COMPF_{base}$* = *Baseline compressor factor*
= See “Baseline Compressor Factor” Table below based on existing baseline compressor type. Where there is no baseline compressor use modulating with blowdown as the baseline type.
*$COMPF_{ee}$* = *Installed compressor factor, actual*
= *If unknown, 0.705*[875]

### Summer Coincident Peak kW Savings Algorithm

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

*Where:*

*CF* = *Coincidence factor*

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[874] Compressor motor nominal HP to full load kW conversion factor.

[875] Efficiency Vermont Technical Reference User Manual (TRM) No. 2015-87C..

= If unknown, see “Compressor Total Hours of Operation and Coincidence Factor, if unknown” below.

## Annual Fossil Fuel Savings Algorithm

n/a

## Annual Water Savings Algorithm

n/a

## Measure Life

The measure life is assumed to be 13 years[876].

## Reference Tables

**Compressor Total Hours of Operation and Coincidence Factor, if unknown[877]**

| Number of shifts | Operating Hours | Coincidence Factor (CF) |
|---|---|---|
| Single shift | 1,976 7 AM – 3 PM, weekdays, minus some holidays and scheduled down time | 0.59 |
| 2 - shift | 3,952 7AM – 11 PM, weekdays, minus some holidays and scheduled down time | 0.95 |
| 3 - shift | 5,928 24 hours per day, weekdays, minus some holidays and scheduled down time | 0.95 |
| 4 - shift | 8,320 24 hours per day, 7 days a week minus some holidays and scheduled down time | 0.95 |

**Baseline Compressor Factor[878]**

| Baseline Compressor | Compressor Factor ($COMPF_{base}$) |
|---|---|
| Modulating w/ Blowdown | 0.890 |
| Load/No Load w/ 1 Gallon-of-storage/$CFM_{Max}$ | 0.909 |
| Load/No Load w/ 3 Gallon-of-storage/$CFM_{Max}$ | 0.831 |
| Load/No Load w/ 5 Gallon-of-storage/$CFM_{Max}$ | 0.806 |

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[876] Based on a review of TRM assumptions from New York (January 2019), Massachusetts (October 2015), Illinois (September 2018), Indiana (July 2015), and Vermont (March 2015). Estimates range from 10 to 15 years.

[877] 2019 Illinois Statewide Technical Reference Manual for Energy Efficiency Version 7.0, Volume 2: Commercial and Industrial Measures.

[878] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp, as sourced from the Efficiency Vermont TRM.(The “variable speed drive” compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

*Appendices*

## A. RETIRED

**Verification.**

Coordination with Other Savings Assessment Activities

Although the TRM will be a critically important tool for both DSM planning and estimation of actual savings, it will not, by itself, ensure that reported savings are the same as actual savings. There are two principal reasons for this:

1. **The TRM itself does not ensure appropriate estimation of savings**. One of the responsibilities of the Independent Program Evaluators will be to assess that the TRM has been used appropriately in the calculation of savings.
2. **The TRM may have assumptions or protocols that new information suggests are outdated**. New information that could inform the reasonableness of TRM assumptions or protocols can surface at any time, but they are particularly common as local evaluations or annual savings verification processes are completed. Obviously, the TRM should be updated to reflect such new information. However, it is highly likely that some such adjustments will be made too late to affect the annual savings estimate of a program administrator for the previous year. Thus, there may be a difference between savings estimates in annual compliance reports and the "actual savings" that may be considered acceptable from a regulatory perspective. However, such updates should be captured in as timely a fashion as possible.

These two issues highlight the fact that the TRM needs to be integrated into a broader process that has two other key components: an annual savings verification process and on-going evaluation.

In our view, an annual savings verification process should have several key features.

1. It should include a review of data tracking systems used to record information on efficiency measures that have been installed. Among other things, this review should assess whether data appear to have been appropriately and accurately entered into the system.
2. It should include a review of all deemed savings assumptions underlying the program administrators' savings claims to ensure that they are consistent with the TRM.
3. It should include a detailed review of a statistically valid, random sample of custom commercial and industrial projects to ensure that custom savings protocols were appropriately applied. At a minimum, engineering reviews should be conducted; ideally, custom project reviews should involve some on-site assessments as well.
4. These reviews should be conducted by an independent organization with appropriate expertise.
5. The participants will need to have a process in place for quickly resolving any disputes between the utilities or program administrators on the one hand and the independent reviewer on the other.

6. The results of the independent review and the resolution of any disagreements should ideally be very transparent to stakeholders.

Such verification ensures that information is being tracked accurately and in a manner consistent with the TRM. However, as important as it is, verification does not ensure that reported savings are “actual savings”. TRMs are never and can never be perfect. Even when the verification process documents that assumptions have been appropriately applied, it can also highlight questions that warrant future analysis that may lead to changes to the TRM. Put another way, evaluation studies are and always will be necessary to identify changes that need to be made to the TRM. Therefore, in addition to annual savings verification processes, evaluations will periodically be made to assess or update the underlying assumption values for critical components of important measure characterizations.

In summary, there should be a strong, sometimes cyclical relationship between the TRM development and update process, annual compliance reports, savings verification processes, and evaluations. As such, we recommend coordinating these activities.

## B. Description of Unique Measure Codes

Each measure included in the TRM has been assigned a unique identification code. The code consists of a string of five descriptive categories connected by underscores, in the following format:
Sector_End Use_Program Type_Measure_MonthYear

A description of the abbreviations used in the codes is provided in the tables below:

| | |
|---|---|
| **SECTOR** | |
| **RS** | **Residential** |
| **CI** | **Commercial & Industrial** |
| **END USE** | |
| **LT** | **Lighting** |
| **RF** | **Refrigeration** |
| **HV** | **Heating, Ventilation, Air Conditioning** |
| **WT** | **Hot Water** |
| **LA** | **Laundry** |
| **SL** | **Shell (Building)** |
| **MO** | **Motors and Drives** |
| **KE** | **Commercial Kitchen Equipment** |
| **PL** | **Plug Load** |
| **PROGRAM TYPE** | |
| **TOS** | **Time of Sale** |
| **NC** | **New Construction** |
| **RF** | **Retrofit** |
| **EREP** | **Early Replacement** |
| **ERET** | **Early Retirement** |
| **DI** | **Direct Install** |

## C. RETIRED

## D. Commercial & Industrial Lighting Operating Hours and Coincidence Factors

### Downstream Programs[879]

**If** both building type and space type are available, hours of use and coincidence factors are broken out by building type, then by space type using the following logic:

- Does the building fit into one of the listed building types in Table D-1?
    - Yes: Does the space fit into one of the building type and space type pairs in Table D-1?
        - Yes: Use data from the matching building and space type in Table D-1.
        - No: Does the space fit into one of the space types in Table D-2?
            - Yes: Use data form the matching space type in Table D-2.
            - No: Use data from the matching building type and space type = "Other" in Table D-1.
    - No: Does the space fit into one of the space types in Table D-2?
        - Yes: Use data form the matching space type in Table D-2.
        - No, Use data from building type = "All" and space type = "Other" in Table D-2.

If the Building Type is known, but the Space Type is unknown, the matching Building Type and "Other" Space Type should be used.

If Building Type is unknown, Building Type "All" and "Other" Space Type should be used.

**Table D-1: C&I Downstream Lighting Parameters by Building and Space Type**[880]

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[879] Downstream programs are programs where the efficiency program's influence is at the end user level such as prescriptive, custom, or new construction programs.

[880] EmPOWER Maryland DRAFT Final Impact Evaluation Deemed Savings (June 1, 2017 – May 31, 2018) Commercial & Industrial Prescriptive, Small Business, and Direct Install Programs, Navigant, March, 2018.

| Building Type | Space Type | Hours of Use | Utility CF | PJM Summer CF | PJM Winter CF |
|---|---|---|---|---|---|
| Education | Auditorium/Gym | 2032 | 0.33 | 0.34 | 0.35 |
| Education | Classroom/Lecture | 1505 | 0.21 | 0.22 | 0.2 |
| Education | Computer Room/Data Processing | 2032 | 0.33 | 0.34 | 0.35 |
| Education | Corridor/Hallways | 5052 | 0.77 | 0.78 | 0.75 |
| Education | Locker and Dressing Room | 2032 | 0.33 | 0.34 | 0.35 |
| Education | Office (Executive/Private) | 2084 | 0.42 | 0.57 | 0.26 |
| Education | Office (General) | 4252 | 0.66 | 0.67 | 0.46 |
| Education | Office (Open Plan) | 2888 | 0.62 | 0.7 | 0.54 |
| Education | Residential | 2032 | 0.33 | 0.34 | 0.35 |
| Education | Storage (Conditioned) | 2032 | 0.33 | 0.34 | 0.35 |
| Education | Vacant (Condtioned) | 2032 | 0.33 | 0.34 | 0.35 |
| Grocery | Retail Sales/Showroom | 7374 | 0.98 | 0.98 | 0.93 |
| Grocery | Storage (Conditioned) | 6027 | 0.84 | 0.84 | 0.82 |
| Grocery | Storage (Walk-In Refrigerator/Freezer) | 5851 | 1.0 | 0.99 | 0.98 |
| Health | Copy Room | 2964 | 0.59 | 0.61 | 0.41 |
| Health | Corridor/Hallways | 6191 | 0.9 | 0.9 | 0.77 |
| Health | Exhibit Display Area/Museum | 2964 | 0.59 | 0.61 | 0.41 |
| Health | Laundry | 2964 | 0.59 | 0.61 | 0.41 |
| Health | Locker and Dressing Room | 2964 | 0.59 | 0.61 | 0.41 |
| Health | Medical Offices and Exam rooms | 2964 | 0.59 | 0.61 | 0.41 |
| Health | Patient Rooms | 2964 | 0.59 | 0.61 | 0.41 |
| Health | Storage (Conditioned) | 2964 | 0.59 | 0.61 | 0.41 |
| Multi-Family | Common Area Hallways[2] | 7669 | 0.87 | 0.87 | 0.88 |
| Multi-Family | Non-Hallway Common Areas[1] | 5091 | 0.76 | 0.75 | 0.63 |
| Office | Computer Room/Data Processing | 2897 | 0.7 | 0.69 | 0.48 |

| | | | | | |
|---|---|---|---|---|---|
| Office | Copy Room | 2897 | 0.7 | 0.69 | 0.48 |
| Office | Corridor/Hallways | 4092 | 0.65 | 0.64 | 0.71 |
| Office | Lobby (Main Entry and Assembly) | 6569 | 0.93 | 0.91 | 0.8 |
| Office | Office (General) | 3009 | 0.7 | 0.7 | 0.48 |
| Office | Smoking Lounge | 2897 | 0.7 | 0.69 | 0.48 |
| Office | Storage (Conditioned) | 2897 | 0.7 | 0.69 | 0.48 |
| Retail | Lobby (Main Entry and Assembly) | 6417 | 0.99 | 0.99 | 0.63 |
| Retail | Office (General) | 3175 | 0.72 | 0.73 | 0.4 |
| Retail | Restrooms | 5816 | 0.94 | 0.94 | 0.7 |
| Retail | Retail Sales/Showroom | 5192 | 0.98 | 0.98 | 0.64 |
| Warehouse/Industrial | Auto Repair Workshop | 5482 | 0.94 | 0.93 | 0.49 |
| Warehouse/Industrial | Comm/Ind Work (General High Bay) | 5103 | 0.92 | 0.94 | 0.86 |
| Warehouse/Industrial | Comm/Ind Work (General Low Bay) | 7110 | 0.98 | 0.98 | 0.78 |
| Warehouse/Industrial | Comm/Ind Work (Precision) | 3338 | 0.71 | 0.69 | 0.44 |
| Warehouse/Industrial | Office (General) | 2868 | 0.74 | 0.74 | 0.36 |
| Warehouse/Industrial | Restrooms | 4213 | 0.53 | 0.53 | 0.47 |
| Warehouse/Industrial | Storage (Conditioned & Walk-In Refrigerator/Freezer) | 4530 | 0.81 | 0.82 | 0.4 |
| Warehouse/Industrial | Storage (Refrigerated/Freezer),Walk-in | 3338 | 0.71 | 0.69 | 0.44 |
| Warehouse/Industrial | Vacant (Condtioned) | 3338 | 0.71 | 0.69 | 0.44 |

*Source: Navigant Commercial and Industrial Long Term Metering Study*

| Building Type | Space Type | Hours of Use | Utility CF | PJM Summer CF | PJM Winter CF |
|---|---|---|---|---|---|
| All | Auto Repair Workshop | 6189 | 0.88 | 0.89 | 0.61 |
| All | Classroom/Lecture | 1584 | 0.24 | 0.24 | 0.20 |
| All | Comm/Ind Work (General High Bay) | 4790 | 0.90 | 0.91 | 0.82 |
| All | Comm/Ind Work (General Low Bay) | 6775 | 0.95 | 0.95 | 0.77 |
| All | Conference Room | 1201 | 0.28 | 0.30 | 0.16 |
| All | Corridor/Hallways | 5670 | 0.86 | 0.86 | 0.73 |
| All | Dining Area | 2962 | 0.48 | 0.53 | 0.51 |
| All | Exercise Centers/Gymnasium | 4833 | 0.81 | 0.82 | 0.60 |
| All | Kitchen/Break room & Food Prep | 3522 | 0.79 | 0.74 | 0.42 |
| All | Library | 1957 | 0.44 | 0.46 | 0.31 |
| All | Loading Dock | 7358 | 0.97 | 0.97 | 0.62 |
| All | Lobby (Main Entry and Assembly) | 5947 | 0.83 | 0.82 | 0.71 |
| All | Lobby (Office Reception/Waiting) | 3425 | 0.84 | 0.87 | 0.49 |
| All | Mechanical/Electrical Room | 5026 | 0.73 | 0.74 | 0.46 |
| All | Office (Executive/Private) | 1753 | 0.42 | 0.44 | 0.20 |
| All | Office (General) | 3001 | 0.67 | 0.67 | 0.43 |
| All | Office (Open Plan) | 3159 | 0.81 | 0.82 | 0.49 |
| All | Other | 3438 | 0.65 | 0.64 | 0.4 |
| All | Parking Garage | 8678 | 0.98 | 0.98 | 0.99 |
| All | Outside/Outdoor Area | 3604 | 0.11 | 0.11 | 0.58 |
| All | Restrooms | 2521 | 0.48 | 0.42 | 0.30 |
| All | Retail Sales/Showroom | 6152 | 0.97 | 0.97 | 0.78 |
| All | Storage (Conditioned & Walk-In Refrigerator/Freezer) | 4672 | 0.81 | 0.81 | 0.44 |
| All | Storage (Unconditioned) | 2930 | 0.66 | 0.64 | 0.40 |

*Source: Navigant Commercial and Industrial Long Term Metering Study*

**Table D-2: C&I Downstream Lighting Parameters by Space Type for Unknown or Unmatched Building Types**[881]

## Midstream Programs[882]

Hours of use and coincidence factors are taken from the matching building type in Table D-3. If the building type is unknown or unmatched, "Other" building type should be used.

**Table D-3: C&I Interior Midstream Lighting Parameters by Building Type**

| Building Type | HOURS | $CF_{UPeak}$ | $CF_{PJM\text{-}S}$ | $CF_{PJM\text{-}W}$ |
|---|---|---|---|---|
| Education | 2,233 | 0.35 | 0.36 | 0.33 |
| Grocery | 7,272 | 0.97 | 0.97 | 0.93 |
| Health | 3,817 | 0.67 | 0.68 | 0.51 |
| Office | 3,044 | 0.70 | 0.69 | 0.49 |
| Other | 4,058 | 0.62 | 0.61 | 0.46 |
| Retail | 4,696 | 0.83 | 0.83 | 0.56 |
| Warehouse/Industrial | 4,361 | 0.80 | 0.80 | 0.50 |

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[881] EmPOWER Maryland DRAFT Final Impact Evaluation Deemed Savings (June 1, 2017 – May 31, 2018) Commercial & Industrial Prescriptive, Small Business, and Direct Install Programs, Navigant, March, 2018.

[882] Midstream programs are programs where the efficiency program's influence is at the distributer level such as midstream programs that buy-down the qualifying efficient product price by incenting the distributer.

## E. Commercial & Industrial Lighting Waste Heat Factors

**Energy and Summer Peak Waste Heat Factors for C&I Lighting – Known HVAC Types**[883]

| State, Utility | Building Type | Demand Waste Heat Factor (WHFd) | | Annual Energy Waste Heat Factor by Cooling/Heating Type (WHFe) | | | |
|---|---|---|---|---|---|---|---|
| | | AC (Utility) | AC (PJM) | AC/ NonElec | AC/ ElecRes | Heat Pump | NoAC/ ElecRes[884] |
| Maryland, BGE | Office | 1.36 | 1.32 | 1.10 | 0.85 | 0.94 | 0.75 |
| | Retail | 1.27 | 1.26 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.44 | 1.44 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.23 | 1.24 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.35 | 1.33 | 1.08 | 0.82 | 0.93 | 0.74 |
| Maryland, SMECO | Office | 1.36 | 1.32 | 1.10 | 0.85 | 0.94 | 0.75 |
| | Retail | 1.27 | 1.26 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.44 | 1.44 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.23 | 1.25 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.35 | 1.33 | 1.08 | 0.82 | 0.93 | 0.74 |
| Maryland, Pepco | Office | 1.36 | 1.32 | 1.10 | 0.85 | 0.94 | 0.75 |
| | Retail | 1.27 | 1.26 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.44 | 1.44 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.23 | 1.25 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.35 | 1.33 | 1.08 | 0.82 | 0.93 | 0.74 |
| Maryland, DPL | Office | 1.35 | 1.32 | 1.10 | 0.85 | 0.94 | 0.75 |
| | Retail | 1.27 | 1.26 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.44 | 1.44 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.22 | 1.23 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.34 | 1.32 | 1.08 | 0.82 | 0.93 | 0.74 |
| | Office | 1.34 | 1.31 | 1.10 | 0.85 | 0.94 | 0.75 |

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[883] EmPOWER Maryland DRAFT Final Impact Evaluation Report Evaluation Year 4 (June 1, 2012 – May 31, 2013) Commercial & Industrial Prescriptive & Small Business Programs, Navigant, March 31, 2014. Values for Washington, D.C. and Delaware assume values from Maryland, Pepco and Maryland, DPL, respectively.

[884] Waste Heat Factors for “NoAC/ElecRes” estimated as at difference between “AC/ElecRes” and “AC/NonElec” plus one.

| State, Utility | Building Type | Demand Waste Heat Factor (WHFd) | | Annual Energy Waste Heat Factor by Cooling/Heating Type (WHFe) | | | |
|---|---|---|---|---|---|---|---|
| | | AC (Utility) | AC (PJM) | AC/ NonElec | AC/ ElecRes | Heat Pump | NoAC/ ElecRes[884] |
| Maryland, Potomac Edison | Retail | 1.27 | 1.25 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.45 | 1.45 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.2 | 1.21 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.33 | 1.31 | 1.08 | 0.82 | 0.93 | 0.74 |
| Washington, D.C., All | Office | 1.36 | 1.32 | 1.10 | 0.85 | 0.94 | 0.75 |
| | Retail | 1.27 | 1.26 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.44 | 1.44 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.23 | 1.25 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.35 | 1.33 | 1.08 | 0.82 | 0.93 | 0.74 |
| Delaware, All | Office | 1.35 | 1.32 | 1.10 | 0.85 | 0.94 | 0.75 |
| | Retail | 1.27 | 1.26 | 1.06 | 0.83 | 0.95 | 0.77 |
| | School | 1.44 | 1.44 | 1.10 | 0.81 | 0.96 | 0.71 |
| | Warehouse | 1.22 | 1.23 | 1.02 | 0.75 | 0.89 | 0.73 |
| | Other | 1.34 | 1.32 | 1.08 | 0.82 | 0.93 | 0.74 |

Note(s): The “Other” building type should be used when the building type is known but not explicitly listed above. A description of the actual building type should be recorded in the project documentation. If cooling and heating equipment types are unknown or the space is unconditioned, assume WHFe = 1.0.

**Winter PJM Demand Waste Heat Factor by Heating System Type**

| Utility | Building Type | Unknown | Gas | Electric Resistance | Heat Pump | None |
|---|---|---|---|---|---|---|
| All Utilities | Office | 0.68 | 1.00 | 0.18 | 0.60 | 1.00 |
| | Retail | 0.83 | 1.00 | 0.41 | 0.71 | 1.00 |
| | School | 0.93 | 1.00 | 0.16 | 0.59 | 1.00 |
| | Warehouse/Industrial | 0.91 | 1.00 | 0.23 | 0.62 | 1.00 |
| | Other | 0.89 | 1.00 | 0.20 | 0.61 | 1.00 |

### F. Commercial & Industrial Full Load Cooling and Heating Hours[*]

**Note: Full load hours for heating and cooling are locked down in Maryland three years June 1, 2020 through May 31, 2023, EXCEPT for boilers, which are locked down one year June 1, 2020 through May 31, 2021**

Full load cooling hours and full load heating hours are broken out by building type and geographic location. The building types and locations are indicated in the following tables.

**Full Load Cooling Hours by Location and Building Type (EFLH$_{COOL}$)[885]**

| Space and/or Building Type | Dover, DE | Wilmington, DE | Baltimore, MD | Hagerstown, MD | Patuxent River, MD | Salisbury, MD | Washington D.C. |
|---|---|---|---|---|---|---|---|
| Assembly | 937 | 922 | 945 | 861 | 1,103 | 909 | 1,143 |
| Education - Community College | 713 | 701 | 718 | 655 | 839 | 691 | 869 |
| Education - Primary School | 293 | 288 | 295 | 269 | 344 | 284 | 357 |
| Education - Relocatable Classroom | 348 | 342 | 351 | 319 | 409 | 337 | 424 |
| Education - Secondary School | 337 | 331 | 340 | 309 | 396 | 327 | 411 |
| Education - University | 787 | 774 | 793 | 723 | 926 | 763 | 960 |
| Grocery | 672 | 662 | 678 | 618 | 791 | 652 | 820 |
| Health/Medical - Hospital | 1,213 | 1,194 | 1,223 | 1,114 | 1,427 | 1,176 | 1,480 |
| Health/Medical - Nursing Home | 645 | 634 | 650 | 592 | 758 | 625 | 786 |
| Lodging - Hotel | 1,816 | 1,787 | 1,831 | 1,668 | 2,137 | 1,760 | 2,215 |
| Manufacturing – Bio Tech/High Tech | 867 | 853 | 874 | 796 | 1,020 | 840 | 1,057 |
| Manufacturing – 1 Shift/Light Industrial | 456 | 449 | 460 | 419 | 537 | 442 | 557 |
| Multi-Family (Common Areas) | 1,509 | 1,485 | 1,521 | 1,386 | 1,776 | 1,463 | 1,841 |
| Office - Large | 727 | 716 | 733 | 668 | 856 | 705 | 887 |
| Office - Small | 629 | 619 | 634 | 577 | 740 | 609 | 767 |
| Restaurant - Fast-Food | 724 | 712 | 730 | 665 | 851 | 701 | 883 |
| Restaurant - Sit-Down | 762 | 750 | 768 | 700 | 897 | 739 | 930 |
| Retail - Multistory Large | 880 | 866 | 887 | 808 | 1,035 | 853 | 1,074 |
| Retail - Single-Story Large | 904 | 890 | 911 | 830 | 1,064 | 876 | 1,103 |
| Retail - Small | 915 | 901 | 923 | 840 | 1,077 | 887 | 1,116 |
| Storage - Conditioned | 243 | 239 | 245 | 223 | 286 | 235 | 296 |
| Warehouse - Refrigerated | 3,886 | 3,824 | 3,917 | 3,569 | 4,572 | 3,767 | 4,740 |

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[885] Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook — Fundamentals. See http://www.neep.org/file/5550/download?token=6THHJ4D7 for calculations.

**Full Load Heating Hours by Location and Building Type for heat pumps (EFLH$_{HEAT}$)[886]**

| Space and/or Building Type | Dover, DE | Wilmington, DE | Baltimore, MD | Hagerstown, MD | Patuxent River, MD | Salisbury, MD | Washington D.C. |
|---|---|---|---|---|---|---|---|
| Assembly | 1,114 | 1,150 | 1,114 | 1,168 | 1,064 | 1,079 | 1,040 |
| Education - Community College | 713 | 736 | 713 | 747 | 681 | 691 | 666 |
| Education - Primary School | 668 | 689 | 668 | 700 | 638 | 647 | 623 |
| Education - Relocatable Classroom | 647 | 668 | 647 | 679 | 618 | 627 | 604 |
| Education - Secondary School | 719 | 742 | 719 | 754 | 687 | 697 | 671 |
| Education - University | 530 | 546 | 530 | 555 | 506 | 513 | 494 |
| Grocery | 984 | 1,015 | 984 | 1,031 | 939 | 953 | 918 |
| Health/Medical - Hospital | 214 | 221 | 214 | 224 | 204 | 207 | 200 |
| Health/Medical - Nursing Home | 932 | 962 | 932 | 977 | 890 | 903 | 870 |
| Lodging - Hotel | 2,242 | 2,313 | 2,242 | 2,350 | 2,140 | 2,172 | 2,092 |
| Manufacturing – Bio Tech/High Tech | 146 | 151 | 146 | 153 | 139 | 141 | 136 |
| Manufacturing – 1 Shift/Light Industrial | 585 | 603 | 585 | 613 | 558 | 567 | 546 |
| Multi-Family (Common Areas) | 256 | 264 | 256 | 268 | 244 | 248 | 239 |
| Office - Large | 221 | 228 | 221 | 231 | 211 | 214 | 206 |
| Office - Small | 440 | 454 | 440 | 461 | 420 | 426 | 411 |
| Restaurant - Fast-Food | 1,226 | 1,265 | 1,226 | 1,285 | 1,170 | 1,188 | 1,144 |
| Restaurant - Sit-Down | 1,131 | 1,167 | 1,131 | 1,185 | 1,079 | 1,096 | 1,055 |
| Retail - Multistory Large | 591 | 609 | 591 | 619 | 564 | 572 | 551 |
| Retail - Single-Story Large | 739 | 762 | 739 | 774 | 705 | 716 | 689 |
| Retail - Small | 622 | 642 | 623 | 652 | 594 | 603 | 581 |
| Storage - Conditioned | 854 | 881 | 854 | 895 | 815 | 828 | 797 |
| Warehouse - Refrigerated | 342 | 353 | 343 | 359 | 327 | 332 | 320 |

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[886] Equivalent Full Load Hours (EFLH) adapted from TECHNICAL REFERENCE MANUAL, State of Pennsylvania Act 129 Energy Efficiency and Conservation Program & Act 213 Alternative Energy Portfolio Standards, June 2016. Mid-Atlantic values have been adjusted for local design temperatures and degree days from 2013 ASHRAE Handbook — Fundamentals. See http://www.neep.org/file/5550/download?token=6THHJ4D7 for calculations.

**Full Load Heating Hours by Location and Building Type for fossil fuel measures ($EFLH_{GAS}$)**

| Space and/or Building Type | Dover, DE | Wilmington, DE | Baltimore, MD | Hagerstown, MD | Patuxent River, MD | Salisbury, MD | Washington D.C. | EFLH Data Source[887] |
|---|---|---|---|---|---|---|---|---|
| Assembly | 1,938 | 1,969 | 1,721 | 1,881 | 1,007 | 1,293 | 1,871 | WG |
| Education - Community College | 864 | 878 | 1,367 | 847 | 447 | 577 | 1,492 | NY |
| Education - Primary School | 564 | 573 | 501 | 547 | 293 | 376 | 544 | WG |
| Education - Relocatable Classroom | 546 | 554 | 485 | 530 | 283 | 364 | 527 | RA |
| Education - Secondary School | 672 | 683 | 882 | 659 | 348 | 448 | 962 | NY |
| Education - University | 1,035 | 1,052 | 1,162 | 1,015 | 536 | 691 | 1,269 | NY |
| Grocery | 984 | 1,015 | 984 | 1,031 | 939 | 953 | 918 | HP |
| Health/Medical - Hospital | 333 | 339 | 296 | 324 | 173 | 222 | 322 | WG |
| Health/Medical - Nursing Home | 1,582 | 1,607 | 1,405 | 1,536 | 822 | 1,056 | 1,528 | WG |
| Lodging - Hotel | 1,367 | 1,389 | 1,214 | 1,328 | 710 | 912 | 1,320 | WG |
| Manufacturing – Bio Tech/High Tech | 146 | 151 | 146 | 153 | 139 | 141 | 136 | HP |
| Manufacturing – 1 Shift/Light Industrial | 775 | 788 | 723 | 760 | 401 | 517 | 789 | NY |
| Multi-Family (Common Areas) | 1,643 | 1,669 | 1,460 | 1,595 | 854 | 1,096 | 1,587 | WG |
| Office - Large | 2,250 | 2,286 | 1,999 | 2,185 | 1,169 | 1,501 | 2,173 | WG |
| Office - Small | 458 | 466 | 437 | 449 | 237 | 306 | 476 | NY |
| Restaurant - Fast-Food | 872 | 886 | 824 | 855 | 451 | 582 | 899 | NY |
| Restaurant - Sit-Down | 904 | 919 | 832 | 887 | 468 | 603 | 908 | NY |
| Retail - Multistory Large | 1,036 | 1,053 | 1,400 | 1,016 | 536 | 691 | 1,528 | NY |
| Retail - Single-Story Large | 739 | 762 | 739 | 774 | 705 | 716 | 689 | HP |
| Retail - Small | 595 | 605 | 552 | 584 | 308 | 397 | 603 | NY |
| Storage - Conditioned | 500 | 508 | 458 | 490 | 259 | 333 | 500 | NY |
| Warehouse - Refrigerated | 342 | 353 | 343 | 359 | 327 | 332 | 320 | HP |

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[887] Al data sources incorporate weather adjustments by geographic location. Data sources include: WG = Analysis of Washington Gas billing data for specific efficiency projects in 2018 – 2019 where heating system capacity could be confirmed; NY = New York TRM version 7.0; RA = ratio approximation from similar buildings and existing ratio of heat pump EFLH in the Maryland/Mid-Atlantic TRM version 9.0; HP = Direct from heat pump EFLH in the Maryland/Mid-Atlantic TRM version 9.0