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1 Purpose of the TRM

The purpose of the Illinois Statewide Technical Reference Manual (TRM) is to provide a transparent and consistent basis for calculating energy (electric kilowatt-hours (kWh) and natural gas therms) and capacity (electric kilowatts (kW)) savings generated by the State of Illinois’ energy efficiency programs which are administered by the state’s largest electric and gas Utilities (collectively, Program Administrators or the Utilities).

The TRM is a technical document that is filed with the Illinois Commerce Commission (Commission or ICC) and is intended to fulfill a series of objectives, including:

- “Serve as a common reference document for all… stakeholders, [Program Administrators], and the Commission, so as to provide transparency to all parties regarding savings assumptions and calculations and the underlying sources of those assumptions and calculations.

- Support the calculation of the Illinois Total Resource Cost test[3] (“TRC”), as well as other cost-benefit tests in support of program design, evaluation and regulatory compliance. Actual cost-benefit calculations and the calculation of avoided costs will not be part of this TRM.

- Identify gaps in robust, primary data for Illinois, that can be addressed via evaluation efforts and/or other targeted end-use studies.

- [Provide] a process for periodically updating and maintaining records, and preserve a clear record of what deemed parameters are/were in effect at what times to facilitate evaluation and data accuracy reviews.

- …[S]upport coincident peak capacity (for electric) savings estimates and calculations for electric utilities in a manner consistent with the methodologies employed by the utility’s Regional Transmission Organization (“RTO”), as well as those necessary for statewide Illinois tracking of coincident peak capacity impacts.”[4]

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1 220 ILCS 5/8-103B and 220 ILCS 5/8-104.
2 The Program Administrators include: Ameren Illinois, ComEd, Peoples Gas, North Shore Gas, and Nicor Gas (collectively, the Utilities).
3 The Illinois TRC test is defined in 220 ILCS 5/8-104(b) and 20 ILCS 3855/1-10.
1.1 Acknowledgements

This document was created through collaboration amongst the members of the Illinois Energy Efficiency Stakeholder Advisory Group (SAG). The SAG is an open forum where interested parties may participate in the evolution of Illinois’ energy efficiency programs. Parties wishing to participate in the SAG process may do so by visiting [http://www.ilsag.info/questions.html](http://www.ilsag.info/questions.html) and contacting the Independent Facilitator at Annette.Beitel@FutEE.biz. Parties wishing to participate in the Technical Advisory Committee (TAC), a subcommittee of the SAG, may do so by contacting the TRM Administrator at iltrmadministrator@veic.org.

<table>
<thead>
<tr>
<th>SAG Stakeholders⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ameren Illinois Company (Ameren)</td>
</tr>
<tr>
<td>Citizen’s Utility Board (CUB)</td>
</tr>
<tr>
<td>City of Chicago</td>
</tr>
<tr>
<td>Commonwealth Edison Company (ComEd)</td>
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<tr>
<td>Elevate Energy</td>
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<td>Energy Resources Center at the University of Illinois, Chicago (ERC)</td>
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<td>Environment IL</td>
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<td>Environmental Law and Policy Center (ELPC)</td>
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<td>Future Energy Enterprises LLC</td>
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<td>Illinois Attorney General’s Office (AG)</td>
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<td>Illinois Commerce Commission Staff (ICC Staff)</td>
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<td>Illinois Department of Commerce and Economic Opportunity (DCEO)</td>
</tr>
<tr>
<td>Independent Evaluators (ADM, Cadmus, Itron, Navigant)</td>
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<td>Metropolitan Mayor’s Caucus (MMC)</td>
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<td>Midwest Energy Efficiency Association (MEEA)</td>
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<tr>
<td>Natural Resources Defense Council (NRDC)</td>
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<td>Nicor Gas</td>
</tr>
<tr>
<td>Peoples Gas and North Shore Gas</td>
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⁵ Being an open forum, this list of SAG stakeholders and participants may change at any time.
### Table 1.1: Document Revision History

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<th>Document Title</th>
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<td>IL-TRM_Effective_010118_v6.0_Vol_1_Overview_020817_Final</td>
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1.2 Summary of Measure Revisions

The following tables summarize the evolution of measures that are new, revised or errata. This version of the TRM contains 86 measure-level changes as described in the following table.

Table 1.2: Summary of Measure Level Changes

<table>
<thead>
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<th>Change Type</th>
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<td>Errata</td>
<td>5</td>
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<td>Revision</td>
<td>68</td>
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<tr>
<td>New Measure</td>
<td>13</td>
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<td>Total Changes</td>
<td>86</td>
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The ‘Change Type’ column indicates what kind of change each measure has gone through. Specifically, when a measure error was identified and the TAC process resulted in a consensus, the measure is identified here as an ‘Errata’. In these instances the measure code indicates that a new version of the measure has been published, and that the effective date of the measure dates back to June 1st, 2016. Measures that are identified as ‘Revised’ were included in the fifth edition of the TRM, and have been updated for this edition of the TRM. Both ‘Revised’ and ‘New Measure(s)’ have an effective date of January 1st, 2018.

The following table provides an overview of the 86 measure-level changes that are included in this version of the TRM.
### Table 1.3: Summary of Measure Revisions

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<th>Volume</th>
<th>End Use</th>
<th>Measure Name</th>
<th>Measure Code</th>
<th>Change Type</th>
<th>Explanation</th>
<th>Impact on Savings</th>
</tr>
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<tr>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Removal of DCEO as program administrator. Update of Program Year dates. Addition of Review Deadline text. Edits to &quot;Energy Efficiency&quot; in Glossary. Edits to Section 3.9 to remove WACC as discount rate and define Nominal and Real societal discount rates. Timing of retiring T12 as a viable baseline pushed back to 1/1/2019.</td>
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<td></td>
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<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Update to deemed gas savings</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Update of ENERGY STAR specification</td>
<td>Increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Addition of CF to peak demand algorithm</td>
<td>Decrease</td>
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<td></td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor)</td>
<td>None</td>
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<tr>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Change to algorithm methodology. Revised source for costs and loadshape.</td>
<td>Dependent on inputs</td>
</tr>
<tr>
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<td></td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Change to algorithm methodology. Revised source for costs and loadshape.</td>
<td>Dependent on inputs</td>
</tr>
<tr>
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<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Change to algorithm methodology. Revised source for costs and loadshape.</td>
<td>Dependent on inputs</td>
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<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Revised source for costs and loadshape.</td>
<td>Dependent on inputs</td>
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<tr>
<td></td>
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<td>N/A</td>
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<td>Revision</td>
<td>Revised source for costs and loadshape.</td>
<td>Dependent on inputs</td>
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<tr>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor). Fixed cost and savings assumptions to be per HP of fan, not per fan.</td>
<td>Dependent on inputs</td>
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<tr>
<td></td>
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<td>N/A</td>
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<td>Revision</td>
<td>Update of source for hot water consumption estimates</td>
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<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor). Addition of Laminar devices for healthcare applications. Additional clarity of source of assumptions added.</td>
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<td>N/A</td>
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<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor).</td>
<td>None</td>
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<tr>
<td>Volume</td>
<td>End Use</td>
<td>Measure Name</td>
<td>Measure Code</td>
<td>Change Type</td>
<td>Explanation</td>
<td>Impact on Savings</td>
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<tr>
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<td>Showerheads</td>
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<td>cost (including labor)</td>
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<td>4.3.8 Controls for Central Domestic Hot Water</td>
<td>CI-HWE-CDHW-V02-180101</td>
<td>Revision</td>
<td>Updated cost assumption. Added loadshape. Updated deemed kWh assumption. Replaced deemed gas with algorithm methodology with defaults. Added distinction of defaults for dormitories v multi-family buildings.</td>
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<td>4.3.10 DHW Boiler Tune-up</td>
<td>CI-HWE-DBTU-V01-180101</td>
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<td>4.4 HVAC End Use</td>
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<td>4.4.1 Air Conditioner Tune-Up</td>
<td>CI-HVC-ACTU-V04-180101</td>
<td>Revision</td>
<td>Addition of deemed methodology based on eQuest modeling.</td>
<td>Dependent on inputs</td>
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<td>4.4.6 Electric Chiller</td>
<td>CI-HVC-CHIL-V05-180101</td>
<td>Revision</td>
<td>Fix of peak savings example.</td>
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<td>4.4.9 Heat Pump Systems</td>
<td>CI-HVC-HPSY-V05-180101</td>
<td>Revision</td>
<td>Update to GSHP measure life assumption. Savings example edited to reflect new code and appropriate efficiency ratings.</td>
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<td>4.4.11 High Efficiency Furnace</td>
<td>CI-HVC-FRNC-V07-180101</td>
<td>Revision</td>
<td>Clarity on discount rate for future cost.</td>
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<td>4.4.13 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)</td>
<td>CI-HVC-PTAC-V08-180101</td>
<td>Revision</td>
<td>Clarity on discount rate for future cost.</td>
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<td>4.4.15 Single-Package and Split System Unitary Air Conditioners</td>
<td>CI-HVC-SPUA-V05-180101</td>
<td>Revision</td>
<td>Addition of Early Replacement requirements and assumptions. Update of measure costs. Update of efficiency rating (EER to IEER) for units greater than 65 kBtu/hr. Clarity on discount rate for future cost.</td>
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<td>4.4.16 Steam Trap Replacement or Repair</td>
<td>CI-HVC-STRE-V05-180101</td>
<td>Revision</td>
<td>Removal of redundant cost assumptions.</td>
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<td>4.4.17 Variable Speed Drives for HVAC Pumps and Cooling</td>
<td>CI-HVC-VSDHP-V04-180101</td>
<td>Revision</td>
<td>Clarity of measure applicability. Removal of 4 fan applications and addition of Cooling Tower Fan assumptions.</td>
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<td>4.4.19 Demand Controlled Ventilation</td>
<td>CI-HVC-DCV-V04-180101</td>
<td>Revision</td>
<td>Fixing the label of one of the savings tables.</td>
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<td>4.4.30 Notched V Belts and Synchronous Belts for HVAC Systems</td>
<td>CI-HVC-NVBE-V03-180101</td>
<td>Revision</td>
<td>Addition of assumptions for Synchronous Belt applications. Clarity added on cost assumption source.</td>
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<td>4.4.32 Combined Heat and Power</td>
<td>CI-HVC-CHAP-V02-180101</td>
<td>Revision</td>
<td>Updated Heat Rate values based upon 2014 eGrid data.</td>
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<td>4.4.34 Destratification Fan</td>
<td>CI-HVC-DSFN-V02-180101</td>
<td>Revision</td>
<td>Fix of example to appropriately use wall area.</td>
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<td>4.4.35 Economizer Repair and Optimization</td>
<td>CI-HVC-ECRP-V02-160601</td>
<td>Errata</td>
<td>Fixing alignment of algorithms to building types. Clarity on applicability of algorithms.</td>
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<td>4.4.38 Covers and Gap Sealers for Room Air Conditioners</td>
<td>CI-HVC-CRAC-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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<td>4.4.39 High Temperature Heating and Ventilation (HTHV) Direct Fired Heater</td>
<td>CI-HVC-HTHV-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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<td>4.5 Lighting End Use Table</td>
<td>N/A</td>
<td>Revision</td>
<td>Decision not to add new or split existing building types. Added language to allow custom entry for installation within a building or application that does not fit with any of the defined building types. Addition of method to estimate exterior hours based on business operating hours.</td>
<td>None</td>
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<td>Lighting</td>
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<td>4.5.1 Commercial Compact Fluorescent Lamp</td>
<td>CI-LTG-CCFL-V07-180101</td>
<td>Revision</td>
<td>Removed ENERGY STAR specification. Updated deemed RES v C&amp;I split. Updated lamp and O&amp;M costs. Edits to measure life to account for PY change. Miscellaneous hours of use updated – and corresponding lifetime calculations.</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps</td>
<td>CI-LTG-T8FX-V06-160601</td>
<td>Errata</td>
<td>Fixing multiple fixture wattage assumptions. Timing of retiring T12 as a viable baseline pushed back to 1/1/2019.</td>
<td>Dependent on inputs</td>
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<tr>
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<td></td>
<td>4.5.4 LED Bulbs and Fixtures</td>
<td>CI-LTG-LEDB-V06-180101</td>
<td>Revision</td>
<td>Updated deemed LED wattage based on ENERGY STAR V2.0 specification.</td>
<td>Increase</td>
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<td>Volume</td>
<td>End Use</td>
<td>Measure Name</td>
<td>Measure Code</td>
<td>Change Type</td>
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<td>4.5.12 T5 Fixtures and Lamps</td>
<td>CI-LTG-T5FX-V05-180101</td>
<td>Revision</td>
<td>Updated deemed RES v C&amp;I split. Updated lamp and O&amp;M costs, using new real discount rate. Miscellaneous hours of use updated — and corresponding lifetime and O&amp;M calculations. Lamp life for LED Agricultural Fixtures updated to reflect mix of T8 and EISA lamps.</td>
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<td>4.5.15 LED Open Sign</td>
<td>CI-LTG-OPEN-V01-180101</td>
<td>New</td>
<td>New Measure</td>
<td></td>
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<td>Refrigeration</td>
<td>4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers</td>
<td>CI-RFG-ECMF-V02-180101</td>
<td>Revision</td>
<td>Updated source of savings assumptions. Removal of restriction to combine ECM with Fan Control measures.</td>
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<td>4.6.6 Evaporator Fan Control for Electrically Commutated Motors</td>
<td>CI-RFG-EVPF-V03-180101</td>
<td>Revision</td>
<td>Updated source of savings assumptions. Limited application to Fan Controls on ECM motors to allow savings to be claimed for both 4.6.4 and 4.6.6. Additional reference added.</td>
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<tr>
<td></td>
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<td>4.6.7 Strip Curtain for Walk in Coolers and Freezers</td>
<td>CI-RFG-CRTN-V04-180101</td>
<td>Revision</td>
<td>Update savings to be based upon square footage of cooler / freezer. Update of efficient equipment definition. Update to lifetime assumption. Update of cost to be per sq ft of door opening.</td>
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<td>4.6.10 High Speed Roll Up Doors</td>
<td>CI-RFG-HSRD-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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<td>Miscellaneous</td>
<td>4.8.5 High Speed Clothes Washer</td>
<td>CI-MSC-HSCW-V01-180101</td>
<td>New</td>
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<td>4.8.6 ENERGY STAR Computers</td>
<td>CI-MSC-COMP-V01-180101</td>
<td>New</td>
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<td>4.8.7 Advance Power Strip – Tier 1 Commercial</td>
<td>CI-MSC-APSC-V01-180101</td>
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<td>4.8.8 High</td>
<td>Transformer</td>
<td>CI-MSC-TRNS-V01-180101</td>
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<td>New Measure</td>
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<td>4.8.9 High</td>
<td>Efficiency Battery Charger</td>
<td>CI-MSC-BACH-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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<td>5.1.6 ENERGY</td>
<td>STAR and CEE Tier 2 Refrigerator</td>
<td>RS-APL-ESRE-V05-180101</td>
<td>Revision</td>
<td>Clarity on discount rate for future cost.</td>
<td>None</td>
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<td>5.1.7 ENERGY</td>
<td>STAR Room Air Conditioner</td>
<td>RS-APL-ESRA-V06-180101</td>
<td>Revision</td>
<td>Clarity on discount rate for future cost.</td>
<td>None</td>
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<td>5.1.11 ENERGY</td>
<td>STAR Water Coolers</td>
<td>RS-APL-WTCL-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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<td>5.2.1 Advanced</td>
<td>Power Strip Tier 1</td>
<td>RS-CEL-SSTR-V03-180101</td>
<td>Revision</td>
<td>Update to lifetime and cost assumption. Addition of Efficiency Kit assumptions. Addition of unknown # of plug assumptions.</td>
<td>None</td>
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<td>5.2.2 Tier 2</td>
<td>Advanced Power Strip</td>
<td>RS-CEL-APS2-V02-180101</td>
<td>Revision</td>
<td>Update to Baseline AV Energy assumption and resulting savings values. Removal of In Service Rate as single assumption in TRM to be additional vendor specific assumption in Classification document. Fixing column heading for BaselineEnergy variable.</td>
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<td>5.3.1 Air Source Heat Pump</td>
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<td>RS-HVC-ASHP-V07-180101</td>
<td>Revision</td>
<td>Cost assumption update.</td>
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<td>5.3.3 Central</td>
<td>Air Conditioning</td>
<td>RS-HVC-CAC1-V07-180101</td>
<td>Revision</td>
<td>Cost assumption update.</td>
<td>None</td>
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<td>5.3.6 Gas High</td>
<td>Efficiency Boiler</td>
<td>RS-HVC-GHEB-V06-180101</td>
<td>Revision</td>
<td>Clarity on discount rate for future cost.</td>
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<td>5.3.7 Gas High</td>
<td>Efficiency Furnace</td>
<td>RS-HVC-GHEF-V07-180101</td>
<td>Revision</td>
<td>Addition of Verified Quality Installation assumptions. Clarity on discount rate for future cost.</td>
<td>None</td>
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<td>5.3.8 Ground</td>
<td>Source Heat Pump</td>
<td>RS-HVC-GSHP-V07-180101</td>
<td>Revision</td>
<td>Correction of typos in natural gas algorithms. Addition of per ton Central AC cost assumption. Clarity on discount rate for future cost.</td>
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<td>5.3.11 Program</td>
<td>mable Thermostat</td>
<td>RS-HVC-PROG-V04-180101</td>
<td>Revision</td>
<td>Update to unknown electric heat percentage assumption.</td>
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<td>5.3.12 Ductless Heat Pumps</td>
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<td>RS-HVC-DHP-V05-180101</td>
<td>Revision</td>
<td>Allowance of whole house application. Addition of TOS, NC and Early Replacement applications.</td>
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<td>5.3.13 Residential Furnace Tune Up</td>
<td>RS-HVC-FTUN-V03-180101</td>
<td>Revision</td>
<td>Addition of fuel switch algorithms and 'Cost effectiveness screening and load reduction forecasting when fuel switching' section. CF based on whole house v zonal application. Updated Heat Rate values based upon 2014 eGrid data. Clarity on discount rate for future cost.</td>
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<td>5.3.15 ENERGY STAR Ceiling Fan</td>
<td>RS-HVC-CFAN-V02-180101</td>
<td>Revision</td>
<td>Edits to measure life to account for PY change.</td>
<td>None</td>
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<td>5.3.16 Advanced Thermostats</td>
<td>RS-HVC-ADTH-V02-180101</td>
<td>Revision</td>
<td>Addition of footnote explaining collaborative evaluation effort for future Addition of %AC assumption in demand calculation. Update to unknown electric heat percentage assumption.</td>
<td>None</td>
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<td>5.4.2 Gas Water Heater</td>
<td>RS-HWE-GWHT-V07-180101</td>
<td>Revision</td>
<td>Clarity on discount rate for future cost.</td>
<td>None</td>
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<td>5.4.3 Heat Pump Water Heaters</td>
<td>RS-HWE-HPWH-V06-180101</td>
<td>Revision</td>
<td>Update to COP estimates for electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>5.4.4 Low Flow Faucet Aerators</td>
<td>RS-HWE-LFFA-V06-180101</td>
<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor).</td>
<td>None</td>
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<td>5.4.5 Low Flow Showerheads</td>
<td>RS-HWE-LFSH-V05-180101</td>
<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor).</td>
<td>None</td>
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<td>5.4.6 Water Heater Temperature Setback</td>
<td>RS-HWE-TMPS-V05-160601</td>
<td>Errata</td>
<td>Addition of In Service Rate for Efficiency Kits</td>
<td>Decrease</td>
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<td>5.4.8 Thermostatic Restrictor Shower Valve</td>
<td>RS-HWE-TRVA-V03-180101</td>
<td>Revision</td>
<td>Clarification of direct install costs being full installation cost (including labor).</td>
<td>None</td>
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<td>5.4.9 Shower Timer</td>
<td>RS-DHW-SHTM-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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<td>5.5.1 Compact Fluorescent Lamp</td>
<td>RS-LTG-ESCF-V06-180101</td>
<td>Revision</td>
<td>Removed ENERGY STAR specification. Updated deemed RES v C&amp;I split. Update In Service Rate assumptions. Clarification that KITS leakage should be through evaluation. Add Leakage deemed values for TOS measures. Updated lamp and O&amp;M costs. Edits to measure life to account for PY change. Update to COP estimates for electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>Volume</td>
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<td>Measure Name</td>
<td>Measure Code</td>
<td>Change Type</td>
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<td>5.5.2</td>
<td>Specialty Compact Fluorescent Lamp</td>
<td>RS-LTG-ESCC-V05-180101</td>
<td>Revision</td>
<td>Removed ENERGY STAR specification. Updated deemed RES v C&amp;I split. Update In Service Rate assumptions. Clarification that KITS leakage should be through evaluation. Add Leakage deemed values for TOS measures. Edits to measure life to account for PY change. Update to COP estimates for electric heat to account for duct losses.</td>
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<td>5.5.3</td>
<td>ENERGY STAR Torchiere</td>
<td>RS-LTG-ESTO-V04-180101</td>
<td>Revision</td>
<td>Addition of leakage deemed values for TOS measures. Update to COP estimates for electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>5.5.4</td>
<td>Exterior Hardwired Compact Fluorescent Lamp (CFL)</td>
<td>RS-LRG-EFOX-V06-180101</td>
<td>Revision</td>
<td>Addition of leakage deemed values for TOS measures. As per TAC decision, these are estimated as 50% of the lamp assumptions. Edits to measure life to account for PY change. Replacement of NPV calc for O&amp;M with lifetime/cost since no baseline shift.</td>
<td>Dependent on inputs</td>
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<td>5.5.5</td>
<td>Interior Hardwired Compact Fluorescent Lamp (CFL)</td>
<td>RS-LTG-IFIX-V06-180101</td>
<td>Revision</td>
<td>Addition of leakage deemed values for TOS measures. As per TAC decision, these are estimated as 50% of the lamp assumptions. Update to COP estimates for electric heat to account for duct losses. Edits to measure life to account for PY change. Replacement of NPV calc for O&amp;M with lifetime/cost since no baseline shift.</td>
<td>Dependent on inputs</td>
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<td>5.5.6</td>
<td>LED Specialty Lamps</td>
<td>RS-LTG-LEDD-V07-180101</td>
<td>Revision</td>
<td>Updated deemed RES v C&amp;I split. Update In Service Rate assumptions. Clarification that KITS leakage should be through evaluation. Add Leakage deemed values for TOS measures. Updated lamp and O&amp;M costs. Addition of NPV calc for EISA compliant lamps. Added Early Replacement assumptions. Update to COP estimates for electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>5.5.7</td>
<td>LED Exit Sign</td>
<td>RS-LTG-LEDE-V02-180101</td>
<td>Revision</td>
<td>Update to COP estimates for electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>5.5.8</td>
<td>LED Screw Based Omnidirectional Bulbs</td>
<td>RS-LTG-LEDA-V05-180101</td>
<td>Revision</td>
<td>Updated deemed LED wattage based on ENERGY STAR V2.0 specification. Updated deemed RES v C&amp;I split.</td>
<td>Dependent on inputs</td>
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<td>Volume</td>
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<td>Measure Code</td>
<td>Change Type</td>
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<td>Shell</td>
<td>5.6.1 Air Sealing</td>
<td>RS-SHL-AIRS-V06-180101</td>
<td>Revision</td>
<td>Update In Service Rate assumptions. Clarification that KITS leakage should be through evaluation. Add Leakage deemed values for TOS measures. Updated lamp and O&amp;M costs, using new real discount rate. Added Early Replacement assumptions. Update to COP estimates for electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>5.6.2 Basement Sidewall Insulation</td>
<td>RS-SHL-BINS-V08-180101</td>
<td>Revision</td>
<td>Update to COP estimate for ‘2015 on’ electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>5.6.3 Floor Insulation Above Crawlspace</td>
<td>RS-SHL-FINS-V08-180101</td>
<td>Revision</td>
<td>Update to COP estimate for ‘2015 on’ electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<tr>
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<td>5.6.4 Wall and Ceiling/Attic Insulation</td>
<td>RS-SHL-AINS-V07-180101</td>
<td>Revision</td>
<td>Update to COP estimate for ‘2015 on’ electric heat to account for duct losses.</td>
<td>Dependent on inputs</td>
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<td>Miscellaneous</td>
<td>5.7.1 Residential High Efficiency Pool Pumps</td>
<td>RS-MSC-RLP-V01-180101</td>
<td>New</td>
<td>New Measure</td>
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| Volume 4: Cross Cutting Measures | Behavior | 6.1.1 Behavior | CC-BEH-BEHP-V02-160601 | Errata | Addition of text to clarify persistence calculations; update of electric persistence factors. Text referring to weather adjustments clarified to give examples rather than a standardized approach for the adjustment. Updated persistence values to reflect a non-linear decay curve for electric savings persistence based on Navigant’s ComEd studies; updated examples and tables to include this change. Updated text to change the effective date of behavioral persistence measure applicability from 6-1-17 to 1-1-18, specifying that all residential HERs-type programs implemented prior to January 1, 2018 will assume a one-year measure life. Clarified that the persistence values in this version of the protocol are specific to residential home energy reports (HERs)-type programs and provided a definition of Residential HERs-type programs. | Dependent on inputs |
### Table 1.4: Summary of Attachment A: IL-NTG Methods Revisions

<table>
<thead>
<tr>
<th>IL-TRM Volume</th>
<th>Sectors</th>
<th>Protocol Name</th>
<th>Change Type</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>Vol. 4</td>
<td>All Sectors</td>
<td>Residential Cross-Cutting Approaches Residential Nonparticipant Spillover Residential Upstream Lighting Residential New Construction Core Non-Residential Spillover Protocol Core Participant Spillover Protocol</td>
<td>Revision</td>
<td>Lowered spillover and nonparticipant spillover threshold to &gt;5 (on a 0-10 scale)</td>
</tr>
<tr>
<td>Vol. 4</td>
<td>All Sectors</td>
<td>Residential Nonparticipant Spillover Prescriptive Rebates (with no audit) Single Family Home Energy Audit Multifamily Residential New Construction Core Non-Residential Spillover Protocol Core Participant Spillover Protocol</td>
<td>Revision</td>
<td>Updated all 0-10 scales using “not at all” and “extremely” anchor definitions</td>
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<tr>
<td>Vol. 4</td>
<td>Commercial, Industrial, and Public Sectors</td>
<td>Core Nonparticipant Spillover Protocol – Measured from End Users</td>
<td>New</td>
<td>Added new Nonparticipant Spillover Protocol. This protocol incorporates the same spillover threshold of &gt;5 as is used in the Participant Spillover Protocol.</td>
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<tr>
<td>Vol. 4</td>
<td>Commercial, Industrial, and Public Sectors</td>
<td>Changed section name from Training and Technical Assistance Protocol to Technical Assistance Protocol</td>
<td>Revision</td>
<td>Revised to use Core Nonresidential Free Ridership Scoring Algorithm with program and non-program components adapted to specific features relevant to Technical Assistance Programs. Impacts of Training courses are to be counted as Spillover</td>
</tr>
<tr>
<td>Vol. 4</td>
<td>Residential and Low Income Sectors</td>
<td>Nonparticipant Spillover Measured from Customers</td>
<td>Revision</td>
<td>Updated methodology for collecting nonparticipant spillover data Removed previous program experience as a potential driver</td>
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<tr>
<td>IL-TRM Volume</td>
<td>Sectors</td>
<td>Protocol Name</td>
<td>Change Type</td>
<td>Explanation</td>
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</tr>
<tr>
<td>Vol. 4</td>
<td>Residential and Low Income Sectors</td>
<td>Residential Upstream Lighting</td>
<td>Revision</td>
<td>Added more detailed spillover and nonparticipant spillover instructions and scoring algorithms to the protocol</td>
</tr>
<tr>
<td>Vol. 4</td>
<td>Residential and Low Income Sectors</td>
<td>Prescriptive Rebates (with no audit)</td>
<td>Revision</td>
<td>Added contractor recommendation as a potential driver of program influence. Updated phrasing of “prior plans” component of the Program Influence Score and its adjustment on the rebate influence. Removed early replacement text and scoring algorithm</td>
</tr>
<tr>
<td>Vol. 4</td>
<td>Residential and Low Income Sectors</td>
<td>Prescriptive Rebates (with no audit) Single Family Home Energy Audit Multifamily Energy Saving Kits and Elementary Education</td>
<td>Revision</td>
<td>Updated the scoring algorithm to use the minimum of the timing, efficiency, and quantity scores to calculate the Non-Program Score</td>
</tr>
<tr>
<td>Vol. 4</td>
<td>Cross-Sector</td>
<td>Behavioral Protocol, Randomized Controlled Trials</td>
<td>Revision</td>
<td>Added language to address negative uplift methodology issue to ensure consistency across evaluations</td>
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</table>
1.3 Enabling ICC Policy

This Illinois Statewide Technical Reference Manual (TRM) was developed to comply with the Illinois Commerce Commission (ICC or Commission) Final Orders from the electric and gas Utilities’ Energy Efficiency Plan dockets. In the Final Orders, the ICC required the utilities to work with the Illinois Department of Commerce and Economic Opportunity (DCEO) and the Illinois Energy Efficiency Stakeholder Advisory Group (SAG) to develop a statewide TRM. See, e.g., ComEd’s Final Order (Docket No. 10-0570, Final Order7 at 59-60, December 21, 2010); Ameren’s Final Order (Docket No. 10-0568, Order on Rehearing8 at 19, May 24, 2011); Peoples Gas/North Shore Gas’ Final Order (Docket No. 10-0564, Final Order at 76, May 24, 2011), and Nicor’s Final Order (Docket No. 10-0562, Final Order9 at 30, May 24, 2011).

As directed in the Utilities’ Efficiency Plan Orders, the SAG had the opportunity to, and also participated in, every aspect of the development of the TRM. Interested members of the SAG participated in weekly teleconferences to review, comment, and participate in the development of the TRM. The active participants in the TRM were designated as the “Technical Advisory Committee” (TAC). The TAC participants include representatives from the following organizations:

- the Utilities (ComEd, Ameren IL, Nicor Gas, Peoples Gas/North Shore Gas),
- Illinois Department of Commerce and Economic Opportunity (DCEO),
- the independent evaluators (ADM Associates, The Cadmus Group, Itron, Navigant Consulting, Michael’s Engineering, Opinion Dynamics Corporation),
- ICC Staff,
- the Illinois Attorney General’s Office (AG),
- Natural Resources Defense Council (NRDC),
- the Environmental Law and Policy Center (ELPC),
- the Citizen’s Utility Board (CUB),
- The University of Illinois at Chicago,
- Future Energy Enterprises,
- Selective participants including; Geothermal Alliance of Illinois, the Geothermal Exchange Organization, Embertec and TrickleStar.

1.4 Development Process

The first edition of the IL-TRM was approved by the Commission in ICC Docket No. 12-052811. The second edition of the IL-TRM was approved by the Commission in ICC Docket No. 13-043712. The policies surrounding the applicability and use of the IL-TRM in planning, implementation, and evaluation were established by the Commission in ICC

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6 The Illinois Utilities subject to this TRM include: Ameren Illinois Company d/b/a Ameren Illinois (Ameren), Commonwealth Edison Company (ComEd), The Peoples Gas Light and Coke Company and North Shore Gas Company, and Northern Illinois Gas Company d/b/a Nicor Gas.
Docket No. 13-0077\textsuperscript{13}. The Commission extended these policies, including the applicability of the IL-TRM, to the Section 16-111.5B energy efficiency programs in ICC Docket No. 14-0588\textsuperscript{14} and most recently in ICC Docket No. 15-0541\textsuperscript{15}, in order to increase certainty for all parties. The third edition of the IL-TRM was approved by the Commission in ICC Docket No. 14-0189\textsuperscript{16}. The fourth edition of the IL-TRM was approved by the Commission in ICC Docket No. 15-0187\textsuperscript{17}. The fifth edition of the IL-TRM was approved by the Commission in ICC Docket No. 16-0171\textsuperscript{18}. This document represents the sixth edition of the IL-TRM and it applies to Section 8-103B and Section 8-104 energy efficiency programs. It contains a series of new measures, as well as a series of errata items\textsuperscript{19} and updates to existing measures that were already present in the first five editions. Like the previous editions, it is a result of an ongoing review process involving the Illinois Commerce Commission (ICC) Staff (Staff or ICC Staff), the Utilities, DCEO, the Evaluators, the SAG TAC, and the SAG. VEIC meets with the SAG and/or the TRM TAC at least once each month to create a high level of transparency and vetting in the development of this TRM.

Measure requests that are submitted by interested parties are ranked based on the following criteria to determine the approximate priority level for order of inclusion in the TRM:

1. **High Priority**
   a. For those existing measures that make up a significant portion of a utilities’ portfolio and/or where the impact of the requested change is high
   b. For new measures where plans are in place to implement in the next program year

2. **Medium Priority**
   a. For existing measures that are a less significant percent of a utilities’ portfolio and value change will not have a significant impact
   b. For new measures where a savings value is estimated but implementation plans not yet developed

3. **Low Priority**
   a. For existing measures that represent a very small percent of a utilities’ portfolio
   b. For new measures that are just beginning to be explored and will not be implemented in the next program year

These rankings are used to align budget and schedule constraints with desired updates from the TRM.

As measure requests are finalized leading up to the next update of the TRM, weekly TAC meetings are often scheduled to maximize the level of collaboration and visibility into the measure characterization process. Where consensus does not emerge on specific measures or issues, those items are identified in a memo, and are not included in the TRM. As a result, this TRM represents a broad consensus amongst the SAG and TAC participants. In

\textsuperscript{13} \url{http://www.icc.illinois.gov/docket/files.aspx?no=13-0077&docId=203903}; 
\url{http://www.icc.illinois.gov/downloads/public/edocket/339744.pdf}


The adopted consensus language concerning the IL-TRM and its applicability to future Section 16-111.5B energy efficiency programs can be accessed from the following link:


\textsuperscript{15} ICC Docket No. 15-0541, \textit{Final Order} at 36, 82-83, December 16, 2015.

\textsuperscript{16} \url{http://www.icc.illinois.gov/docket/files.aspx?no=14-0189&docId=210478}; 

\textsuperscript{17} \url{http://www.icc.illinois.gov/docket/files.aspx?no=15-0187&docId=226161}; 
\url{http://www.icc.illinois.gov/downloads/public/Illinois_Statewide_TRM_Effective_060115_Final_022415_Clean.pdf}

\textsuperscript{18} \url{https://www.icc.illinois.gov/downloads/public/IL-TRM%20Version%205.0%20Dated%20February%202016%20%20Compiled%20Volumes%201-4.pdf}

\textsuperscript{19} Errata as well as links to the official IL-TRM documents, dockets, and policy documents are available on the following ICC webpage:  \url{http://www.icc.illinois.gov/Electricity/programs/TRM.aspx}
keeping with the goal of transparency, all of the comments and their status to-date are available through the TAC SharePoint web site, https://portal.veic.org.

For each measure characterization, this TRM includes engineering algorithm(s) and a value(s) for each parameter in the equation(s). These parameters have values that fall into one of three categories: a single deemed value, a lookup table of deemed values or an actual value such as the capacity of the equipment. The TRM makes extensive use of lookup tables because they allow for an appropriate level of measure streamlining and customization within the context of an otherwise prescriptive measure.

Accuracy is the overarching principle that governs what value to use for each parameter. When it is explicitly allowed within the text of the measure characterization, the preferred value is the actual or on-site value for the individual measure being implemented. The deemed values\textsuperscript{20} in the lookup tables are the next most accurate choice, and in the absence of either an actual value or an appropriate value in a lookup table, the single, deemed value\textsuperscript{20} should be used. As a result, this single, deemed value can be thought of as a default value for that particular input to the algorithm.

A single deemed savings estimate is produced by any given combination of an algorithm and the allowable input values for each of its parameters. In cases where lookup tables are provided, there is a range of deemed savings estimates that are possible, depending on site-specific factors such as equipment capacity, location and building type.

Algorithms and their parameter values are included for calculating estimated:

- Gross annual electric energy savings (kWh)
- Gross annual natural gas energy savings (therms)
- Gross electric summer coincident peak demand savings (kW)

To support cost-effectiveness calculations, parameter values are also included for:

- Incremental costs ($)
- Measure life (years)
- Operation and maintenance costs ($)
- Water (gal) and other resource savings where appropriate.

### 1.4.1 Reliability Review

The process of incorporating new and better information into the TRM occurs annually as new measures and errors are identified, program designs change, old measures are dropped from programs, or other external events (such as code and standard changes or new evaluations and other data) warrant a review of assumptions. However, not all measures have updates triggered by such events, and some measures continue to appear in the TRM without ongoing review. Short of proactively identified issues that would trigger an update to a TRM characterization, a regular reliability review should be undertaken to assess that the information in older measures is still relevant and reliable. This review will include a general appraisal of reasonableness and continued program relevancy and an update of any assumptions to reflect new information.

To ensure that measures initially developed in the past and not recently revisited are updated and retired as needed, each measure is given a Review Deadline — a date that triggers a reliability review. This Review Deadline is established for each measure based on factors such as expected revisions to energy codes or federal standards; knowledge of upcoming evaluation or research efforts; knowledge of rapidly changing technology, cost, baselines, or other factors; or expected shifts in current customer practices. No Review Deadline is longer than six years from the date of the

\textsuperscript{20}Emphasis has been added to denote the difference between a “deemed value” and a “deemed savings estimate”. A deemed value refers to a single input value to an algorithm, while a deemed savings estimate is the result of calculating the end result of all of the values in the savings algorithm.
initial characterization or last update of a measure. The TRM Administrator will propose Review Deadlines for each measure, and they are reviewed and approved by the TAC. The Review Deadline for each measure is indicated in the measure characterization within the TRM. For example, a Review Deadline specified as 1/1/2019 means that the measure will be reviewed no later than the annual IL-TRM update process that occurs in 2018, in advance of the 1/1/2019 Review Deadline. Following a review and/or update, a new Review Deadline will be assigned to that measure.
2 Organizational Structure

The organization of this document follows a three-level format. These levels are designed to define and clarify what the measure is and where it is applied.

1. Market Sectors Volumes

   o This level of organization specifies the type of customer the measures apply to, either Commercial and Industrial (provided in Volume 2), Residential (provided in Volume 3) or cross-cutting measures, such as Behavior Persistence (provided in Volume 4, together with Attachments including the documentation of Illinois Statewide Net-to-Gross methodologies).

   o Answers the question, “What category best describes the customer?”

2. End-use Category

   o This level of organization represents most of the major end-use categories for which an efficient alternative exists. The following table lists all of the end-use categories in this version of the TRM.

   o Answers the question, “To what end-use category does the measure apply?”

<table>
<thead>
<tr>
<th>Volume 2: Commercial and Industrial Market Sector</th>
<th>Volume 3: Residential Market Sector</th>
<th>Volume 4: Cross-Cutting Measures and Attachments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Equipment</td>
<td>Appliances</td>
<td>Behavior</td>
</tr>
<tr>
<td>Food Service Equipment</td>
<td>Consumer Electronics</td>
<td></td>
</tr>
<tr>
<td>Hot Water</td>
<td>Hot Water</td>
<td></td>
</tr>
<tr>
<td>HVAC</td>
<td>HVAC</td>
<td></td>
</tr>
<tr>
<td>Lighting</td>
<td>Lighting</td>
<td></td>
</tr>
<tr>
<td>Refrigeration</td>
<td>Shell</td>
<td></td>
</tr>
<tr>
<td>Compressed Air</td>
<td>Miscellaneous</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Measure & Technology

   o This level of organization represents individual efficient measures such as CFL lighting and LED lighting, both of which are individual technologies within the Lighting end-use category.

   o Answers the question, “What technology defines the measure?”

This organizational structure is silent on which fuel the measure is designed to save; electricity or natural gas. By organizing the TRM this way, measures that save on both fuels do not need to be repeated. As a result, the TRM will be easier to use and to maintain.

2.1 Measure Code Specification

In order to uniquely identify each measure in the TRM, abbreviations for the major organizational elements of the TRM have been established. When these abbreviations are combined and delimited by a dash (’-‘) a unique, 18-character alphanumeric code is formed that can be used for tracking the measures and their associated savings estimates. Measure codes appear at the end of each measure and are structured using five parts.

\[
\text{Code Structure} = \text{Market} + \text{End-use Category} + \text{Measure} + \text{Version #} + \text{Effective Date}
\]

21 Note that the Public sector buildings and low income measures are not listed as a separate Market Sector. The Public building type is one of a series of building types that are included in the appropriate measures in the Commercial and Industrial Sector.

22 Please note that this is not an exhaustive list of end-uses and that others may be included in future versions of the TRM.
For example, the commercial boiler measure is coded: “CI-HVC-BLR-V01-120601”

Table 2.2: Measure Code Specification Key

<table>
<thead>
<tr>
<th>Market (@@)</th>
<th>End-use (@@@)</th>
<th>Measure (@@@@)</th>
<th>Version (V##)</th>
<th>Effective Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>CI (C&amp;I)</td>
<td>AGE (Agricultural Equipment)</td>
<td>BLR_</td>
<td>V01</td>
<td>YYMMDD</td>
</tr>
<tr>
<td>RS (Residential)</td>
<td>APL (Appliances)</td>
<td>T5FX</td>
<td>V02</td>
<td>YYMMDD</td>
</tr>
<tr>
<td>CC (Cross-Cutting)</td>
<td>BEH (Behavior)</td>
<td>T8FX</td>
<td>V03</td>
<td>YYMMDD</td>
</tr>
<tr>
<td></td>
<td>CEL (Consumer Electronics)</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td>CPA (Compressed Air)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FSE (Food Service Equipment)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HVC (HVAC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HWE (Hot Water)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LTG (Lighting)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MSC (Miscellaneous)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RFG (Refrigeration)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SHL (Shell)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2 Components of TRM Measure Characterizations

Each measure characterization uses a standardized format that includes at least the following components. Measures that have a higher level of complexity may have additional components, but also follow the same format, flow and function.

**DESCRIPTION**

Brief description of measure stating how it saves energy, the markets it serves and any limitations to its applicability.

**DEFINITION OF EFFICIENT EQUIPMENT**

Clear definition of the criteria for the efficient equipment used to determine delta savings. Including any standards or ratings if appropriate.

**DEFINITION OF BASELINE EQUIPMENT**

Clear definition of the efficiency level of the baseline equipment used to determine delta savings including any standards or ratings if appropriate. If a Time of Sale measure the baseline will be new base level equipment (to replace existing equipment at the end of its useful life or for a new building). For Early Replacement or Early Retirement measures the baseline is the existing working piece of equipment that is being removed.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected duration in years (or hours) of the savings. If an early replacement measure, the assumed life of the existing unit is also provided.

**DEEMED MEASURE COST**

For time of sale measures, incremental cost from baseline to efficient is provided. Installation costs should only be included if there is a difference between each efficiency level. For Early Replacement the full equipment and install cost of the efficient installation is provided in addition to the full deferred hypothetical baseline replacement cost.

**LOADSHAPE**

The appropriate loadshape to apply to electric savings is provided.
COINCIDENCE FACTOR
The summer coincidence factor is provided to estimate the impact of the measure on the utility’s system peak – defined as 1PM to hour ending 5PM on non-holiday weekdays, June through August.

<table>
<thead>
<tr>
<th>Algorithm</th>
</tr>
</thead>
</table>

CALCULATION OF ENERGY SAVINGS
Algorithms are provided followed by list of assumptions with their definition.
If there are no Input Variables, there will be a finite number of Output values. These will be identified and listed in a table. Where there are custom inputs, an example calculation is often provided to illustrate the algorithm and provide context.

ELECTRIC ENERGY SAVINGS

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NATURAL GAS SAVINGS

WATER IMPACT DESCRIPTIONS AND CALCULATION

DEEMED O&M COST ADJUSTMENT CALCULATION
Only required if the operation and maintenance cost for the efficient case is different to the baseline.

MEASURE CODE

REVIEW DEADLINE
If not otherwise updated as part of an identified new TRM issue request before this Review Deadline, the measure will undergo a reliability review for reasonableness, continued program relevancy, and update of material assumptions during the update cycle prior to this deadline.

2.3 Variable Input Tables
Many of the measures in this TRM require the user to select the appropriate input value from a list of inputs for a given parameter in the savings algorithm. Where the TRM asks the user to select the input, look-up tables of allowable values are provided. For example, a set of input parameters may depend on building type; while a range of values may be given for each parameter, only one value is appropriate for any specific building type. If no table of alternative inputs is provided for a particular parameter, then the single deemed value will be used, unless the measure has a custom allowable input.

2.3.1 C&I Custom Value Use in Measure Implementation
This section defines the requirements for capturing Custom variables that can be used in place of defaults for select assumptions within the prescriptive measures defined in this statewide TRM. This approach is to be used when a variable in a measure formula can be replaced by a verifiable and documented value that is not presented in the TRM. This approach assumes that the algorithms presented in the measure are used as stated and only allows changes to certain variable values and is not a replacement algorithm for the measure. A custom variable is when customer input is provided to define the number or the value is measured at the site. Custom values can also be supplied from product data of the measure installed. In certain cases the custom data can be provided from a documented study or report that is applicable to the measure. Custom variables and potential sources are clearly
defined in the specific measures where “Actual” or “Custom” is noted.

In exceptional cases where the participant, program administrator, and independent evaluator all agree that the TRM algorithm for a particular energy efficiency measure does not accurately characterize the energy efficiency measure within a project due to the complexity in the design and configuration of the particular energy efficiency project, a more comprehensive custom engineering and financial analysis may be used that more accurately incorporates the attributes of the measure in the complex energy efficiency project. In such cases and consistent with Commission policy adopted in ICC Docket No. 13-0077, Program Administrators are subject to retrospective evaluation risk (retroactive adjustments to savings based on ex post evaluation findings) for such projects utilizing customized savings calculations.

2.4 Program Delivery & Baseline Definitions

The measure characterizations in this TRM are not grouped by program delivery type. As a result, the measure characterizations provided include information and assumptions to support savings calculations for the range of program delivery options commonly used for the measure. The organizational significance of this approach is that multiple baselines, incremental costs, O&M costs, measure lives and in-service rates are included in the measure characterization(s) that are delivered under two or more different program designs. Values appropriate for each given program delivery type are clearly specified in the algorithms or in look-up tables within the characterization.

Care has been taken to clearly define in the measure’s description the types of program delivery that the measure characterization is designed to support. However, there are no universally accepted definitions for a particular program type, and the description of the program type(s) may differ by measure. Nevertheless, program delivery types can be generally defined according to the following table. These are the definitions used in the measure descriptions, and, when necessary, individual measure descriptions may further refine and clarify these definitions of program delivery type.

<table>
<thead>
<tr>
<th>Program</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale (TOS)</td>
<td>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 or contractor based programs as examples. Baseline = New equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: CFL rebate</td>
</tr>
<tr>
<td>New Construction (NC)</td>
<td>Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices. Baseline = Building code or federal standards. Efficient Case = The program’s level of building specification Example: Building shell and mechanical measures</td>
</tr>
<tr>
<td>Retrofit (RF)</td>
<td>Definition: A program that upgrades existing equipment before the end of its useful life. Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure’s life. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Air sealing and insulation</td>
</tr>
<tr>
<td>Early Replacement (ERE)</td>
<td>Definition: A program that replaces existing equipment before the end of its expected life. Baseline = Dual; it begins as the existing equipment and shifts to new baseline equipment after the expected life of the existing equipment is over. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Refrigerators, freezers</td>
</tr>
</tbody>
</table>

Table 2.3: Program Delivery Types
<table>
<thead>
<tr>
<th>Program</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Retirement (ERET)</td>
<td>Definition: A program that retires duplicative equipment before its expected life is over. Baseline = The existing equipment, which is retired and not replaced. Efficient Case = Zero because the unit is retired. Example: Appliance recycling</td>
</tr>
<tr>
<td>Direct Install (DI)</td>
<td>Definition: A program where measures are installed during a site visit. Baseline = Existing equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Lighting and low-flow hot water measures</td>
</tr>
<tr>
<td>Efficiency Kits (KITS)</td>
<td>Definition: A program where measures are provided free of charge to a customer in an Efficiency Kit. Baseline = Existing equipment. Efficient Case = New, premium efficiency equipment above federal and state codes and standard industry practice. Example: Lighting and low-flow hot water measures</td>
</tr>
</tbody>
</table>

The concept and definition of the baseline is a key element of every measure characterization and is directly related to the program delivery type. Without a clear definition of the baseline, the savings algorithms cannot be adequately specified and subsequent evaluation efforts would be hampered. As a result, each measure has a detailed description (and in many cases, specification) of the specific baseline that should be used to calculate savings. Baselines in this TRM fall into one of the following four categories, and are organized within each measure characterization by the program delivery type to which it applies.

1. **Building Code**: As defined by the minimum specifications required under state energy code or applicable federal standards.
2. **Existing Equipment**: As determined by the most representative (or average) example of equipment that is in the existing stock. Existing equipment baselines apply over the equipment’s remaining useful life.
3. **New Equipment**: As determined by the equipment that represents standard practice in the current market environment. New equipment baselines apply over the effective useful life of the measure.
4. **Dual Baseline**: A baseline that begins as the existing equipment and shifts to new equipment after the expected life of the existing equipment is over.
3 Assumptions

The information contained in this TRM contains VEIC’s recommendations for the content of the Illinois TRM. Sources that are cited within the TRM have been chosen based on two priorities, geography and age. Whenever possible and appropriate, VEIC has incorporated Illinois-specific information into each measure characterization. The Business TRM documents from Ameren and ComEd were reviewed, as well as program and measure specific data from evaluations, efficiency plans, and working documents.

The assumptions for these characterizations rest on our understanding of the information available. In each case, the available Illinois and Midwest-specific information was reviewed, including evaluations and support material provided by the Illinois Utilities.

When Illinois or region-specific evaluations or data were not available, best practice research and data from other jurisdictions was used, often from west and east-coast states that have allocated large amounts of funding to evaluation work and to refining their measure characterization parameters. As a result, much of the most-defensible information originates from these regions. In every case, VEIC used the most recent, well-designed, and best-supported studies and only if it was appropriate to generalize their conclusions to the Illinois programs.

3.1 Footnotes & Documentation of Sources

Each new and updated measure characterization is supported by a work paper, which is posted to the SharePoint web site (https://portal.veic.org).23 Both the work paper and the measure characterizations themselves use footnotes to document the references that have been used to characterize the technology. The reference documents are too numerous to include in an Appendix and have instead been posted to the TRM’s Sharepoint website. These files can be found in the ‘Sources and Reference Documents’ folder in the main directory, and are also posted to the SAG’s public web site (http://www.ilsag.info/technical-reference-manual.html).

3.2 General Savings Assumptions

The TRM savings estimates are expected to serve as average, representative 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.

- All estimates of energy (kWh or therms) and peak (kW) savings are for first-year savings, not lifetime savings.
- Unless otherwise noted, measure life is defined to be the life of an energy consuming measure, including its equipment life and measure persistence.
- Where deemed values for savings are provided, they represent the average energy (kWh or therms) or peak (kW) savings that could be expected from the average of all measures that might be installed in Illinois in the program year.
- In general, the baselines included in the TRM are intended to represent average conditions in Illinois. Some are based on data from the state, such as household consumption characteristics provided by the Energy Information Administration. Some are extrapolated from other areas, when Illinois data are not available.

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23 To gain access to the SharePoint web site, please contact the TRM Administrator at iltrmadministrator@veic.org.
3.3 Shifting Baseline Assumptions

The TRM anticipates the effects of changes in efficiency codes and standards on affected measures. When these changes take effect, a shift in the baseline is usually required. This complicates the measure savings estimation somewhat, and will be handled in future versions of the TRM by describing the choice of and reasoning behind a shifting baseline assumption. In this version of the TRM, this applies to CFLs and T5/T8 Linear Fluorescents, Furnaces and Early Replacement Measures.

3.3.1 CFL and T5/T8 Linear Fluorescents Baseline Assumptions

Specific reductions in savings have been incorporated for CFL measures that relate to the shift in appropriate baseline due to changes in Federal Standards for lighting products. Federal legislation (stemming from the Energy Independence and Security Act of 2007) mandates a phase-in process beginning in 2012 for all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs, in essence beginning the phase-out of the current style, or “standard”, incandescent bulbs. In 2012, standard 100W incandescent bulbs will no longer be manufactured, followed by restrictions on standard 75W bulbs in 2013 and 60W and 40W bulbs in 2014. The baseline for the CFL measure in the corresponding program years starting June 1 each year will therefore become bulbs (improved or “efficient” incandescent, or halogen) that meet the new standard and have the same lumen equivalency. Those products can take several different forms we can envision now and perhaps others we do not yet know about. Halogens are one of those possibilities and have been chosen to represent a baseline at that time. To account for this shifting baseline, annual savings are reduced within the lifetime of the measure. Other lighting measures will also have baseline shifts (for example screw based LED and CFL fixtures) that will result in significant impacts to annual estimated savings in later years.

In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline was pushed back in v6.0 to 1/1/2019, and will be revisited in future update sessions.

3.3.2 Early Replacement Baseline Assumptions

A series of measures have an option to choose an Early Replacement Baseline if the following conditions are met:

Early Replacement determination will be based on meeting the following conditions:
• The existing unit is operational when replaced, or
• The existing unit requires minor repairs (see table below) 24.

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum repair cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>$918</td>
</tr>
<tr>
<td>Central Air Conditioner</td>
<td>$734</td>
</tr>
<tr>
<td>Boiler</td>
<td>$709</td>
</tr>
<tr>
<td>Furnace</td>
<td>$528</td>
</tr>
<tr>
<td>Ground Source Heat Pump</td>
<td>&lt;$249 per ton</td>
</tr>
</tbody>
</table>

• All other conditions will be considered Time of Sale.

The Baseline efficiency of the existing unit replaced:

24 The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.

• If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the “New Baseline” column below:

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum efficiency for Actual</th>
<th>New Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>10 SEER</td>
<td>14 SEER</td>
</tr>
<tr>
<td>Central Air Conditioner</td>
<td>10 SEER</td>
<td>13 SEER</td>
</tr>
<tr>
<td>Boiler</td>
<td>75% AFUE</td>
<td>82% AFUE</td>
</tr>
<tr>
<td>Furnace</td>
<td>75% AFUE</td>
<td>80% AFUE</td>
</tr>
<tr>
<td>Ground Source Heat Pump</td>
<td>10 SEER</td>
<td>13 SEER</td>
</tr>
</tbody>
</table>

• If the operational status, repair cost or efficiency of the existing unit is unknown, the Baseline efficiency is the “New Baseline” column above.

3.3.3 Furnace Baseline

The prior national standard for residential oil and gas furnaces was 78% AFUE. DOE raised the standard in 2007 to 80% AFUE, effective 2015. However, virtually all furnaces on the market have an AFUE of 80% or better, which prompted states and environmental and consumer groups to sue DOE over its 2007 decision. In April 2009, DOE accepted a “voluntary remand” in that litigation. In October 2009, manufacturers and efficiency advocates negotiated an agreement that, for the first time, included different standard levels in three climate regions: the North, South, and Southwest. DOE issued a direct final rule (DFR) in June 2011 reflecting the standard levels in the consensus agreement. The DFR became effective on October 25, 2011 establishing new standards: In the North, most furnaces will be required to have an AFUE of 90%. The 80% AFUE standard for the South and Southwest will remain unchanged at 80%. Oil furnaces will be required to have an AFUE of 83% in all three regions. The amended standards will become effective in May 2013 for non-weatherized furnaces and in January 2015 for weatherized furnaces. DOE estimates that the standards will save about 3.3 quads (quadrillion Btu) of energy over 30 years and yield a net present value of about $14 billion at a 3 percent discount rate.

Update: On January 14th 2013, the U.S. Department of Energy (DOE) proposed to settle a lawsuit brought by the American Public Gas Association (APGA) that seeks to roll back gas furnace efficiency standards. As a result, the new standards, completed in 2011 and slated to take effect in May 2013, would be eliminated in favor of yet another round of DOE hearings and studies. Even if DOE completes a new rulemaking in two years, it’s unlikely to take effect before 2020.25

As a result, each of the furnace measures contains the following language describing the baseline assumption:

“Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline will be adjusted when the Federal Standard is updated.”

3.4 Glossary

Baseline Efficiency: The assumed standard efficiency of equipment, absent an efficiency program.

Building Types26:

Note where a measure installation is within a building or application that does not fit with any of the defined building

26 Source: US EPA, www.energystar.gov, Space Type Definitions, or definitions as developed through the Technical Advisory Committee.
types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assisted Living MultiFamily</td>
<td>Applies to residential buildings of three of more units with staff to assist the occupants. Gross Floor Area should include all fully-enclosed space within the exterior walls of the building(s) including individual rooms or units, wellness centers, exam rooms, community rooms, small shops or service areas for residents and visitors (e.g. hair salons, convenience stores), staff offices, lobbies, atriums, cafeterias, kitchens, storage areas, hallways, basements, stairways, corridors between buildings, and elevator shafts.</td>
</tr>
<tr>
<td>Auditorium/Assembly</td>
<td>Applies to any performance space such as a theater, arena, or hall. Gross Floor Area should include all space within the building(s), including seating, stage and backstage areas, food service areas, retail areas, rehearsal studios, administrative/office space, mechanical rooms, storage areas, elevator shafts, and stairwells.</td>
</tr>
<tr>
<td>Childcare/Pre-school</td>
<td>Applies to any building providing childcare to pre-kindergarten age children.</td>
</tr>
<tr>
<td>College/University</td>
<td>Applies to facility space used for higher education. Relevant buildings include administrative headquarters, residence halls, athletic and recreation facilities, laboratories, etc. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc.</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Applies to facility space used for the retail sale of a limited selection of food and beverage products. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas (refrigerated and non-refrigerated), and administrative areas.</td>
</tr>
<tr>
<td>Elementary School</td>
<td>Applies to a school serving children in any grades from Kindergarten through sixth grade. The total gross floor area should include all supporting functions such as administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoria, laboratory classrooms, portable classrooms, greenhouses, stairways, atria, elevator shafts, small landscaping sheds, storage areas, etc.</td>
</tr>
<tr>
<td>Exterior</td>
<td>Applies to unconditioned spaces that are outside of the building envelope.</td>
</tr>
<tr>
<td>Garage</td>
<td>Applies to unconditioned spaces either attached or detached from the primary building envelope that are not used for living space.</td>
</tr>
<tr>
<td>Grocery</td>
<td>Applies to facility space used for the retail sale of food and beverage products. It should not be used by restaurants. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas (refrigerated and non-refrigerated), administrative areas, stairwells, atria, lobbies, etc.</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>Applies to a facility space used to provide diagnosis and treatment for medical, dental, or psychiatric outpatient care. Gross Floor Area should include all space within the building(s) including offices, exam rooms, laboratories, lobbies, atriums, conference rooms and auditoriums, employee break rooms and kitchens, rest rooms, elevator shafts, stairways, mechanical rooms, and storage areas.</td>
</tr>
<tr>
<td>High School/Middle School</td>
<td>Applies to facility space used as a school building for 7th through 12th grade students. This does not include college or university classroom facilities and laboratories, vocational, technical, or trade schools. The total gross floor area should include all supporting functions such as administrative space, conference rooms, kitchens used by staff, lobbies, cafeterias, gymnasiums, auditoria, laboratory classrooms, portable classrooms, greenhouses, stairways, atria, elevator shafts, small landscaping sheds, storage areas, etc.</td>
</tr>
<tr>
<td>Hospital</td>
<td>Applies to a general medical and surgical hospital (including critical access hospitals and children’s hospitals) that is either a stand-alone building or a campus of buildings. Spaces more accurately characterized as a Healthcare Clinic should use that definition. The definition of Hospital accounts for all space types that are located within the Hospital</td>
</tr>
<tr>
<td>Building Type</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hotel/Motel Combined (All Spaces)</td>
<td>Applies to buildings that rent overnight accommodations on a room/suite basis, typically including a bath/shower and other facilities in guest rooms. The total gross floor area should include all interior space, including guestrooms, halls, lobbies, atria, food preparation and restaurant space, conference and banquet space, health clubs/spas, indoor pool areas, and laundry facilities, as well as all space used for supporting functions such as elevator shafts, stairways, mechanical rooms, storage areas, employee break rooms, back-of-house offices, etc. Hotel does not apply to fractional ownership properties such as condominiums or vacation timeshares. Hotel properties should be owned by a single entity and have rooms available on a nightly basis. Where distinction between Hotel and Motel is necessary: Hotel: Room entrances and Corridors are located in the interior of the building. Corridors are conditioned spaces. Building can be significantly larger in size/height. Motel: Room entrances and Corridors are located on the exterior of the building. Corridors are not conditioned spaces. Buildings tend to be two to three stories in height.</td>
</tr>
<tr>
<td>Hotel/Motel Common Areas</td>
<td>All the common areas open to guests of the hotel such as the lobby, corridors and stairways, and other spaces that may have continuous or large lighting and HVAC hours.</td>
</tr>
<tr>
<td>Hotel/Motel Guest Room</td>
<td>Applies to the guest rooms of the hotel or motel. These spaces are occupied intermittently.</td>
</tr>
<tr>
<td>Low-use Small Business</td>
<td>Any business type with low (&lt;3000) operating hours (provided as option in lighting measures).</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Applies to buildings that are dedicated to manufacturing activities. Includes light industry buildings characterized by consumer product and component manufacturing and heavy industry buildings typically characterized by a plant that includes a main production area that has high ceilings and contains heavy equipment used for assembly line production. These building types may be distinguished by categorizing NAICS (SIC) codes according to the needs of the Program Administrator.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Applies to spaces that do not fit clearly within any available categories should be designated as “miscellaneous”.</td>
</tr>
<tr>
<td>Multifamily-Mid Rise</td>
<td>Applies to residential buildings with up to four floors, including all public and multiuse spaces within the building envelope. Small Multifamily buildings best described as a house should use the residential measure characterizations.</td>
</tr>
<tr>
<td>Multifamily-High Rise Combined (All Spaces)</td>
<td>Applies to residential buildings with five or more floors, including all public and multiuse spaces within the building envelope. Gross Floor Area should include all fully-enclosed space within the exterior walls of the building(s) including living space in each unit (including occupied and unoccupied units), interior common areas (e.g. lobbies, offices, community rooms, common kitchens, fitness rooms, indoor pools), hallways, stairwells, elevator shafts, connecting corridors between buildings, storage areas, and mechanical space such as a boiler room. Open air stairwells, breezeways, and other similar areas that are not fully-enclosed should not be included in the Gross Floor Area.</td>
</tr>
<tr>
<td>Multifamily-High Rise Common Areas</td>
<td>All the common areas open to occupants of the building such as the lobby, corridors and stairways, and other spaces that may have continuous or high lighting and HVAC hours.</td>
</tr>
<tr>
<td>Multifamily-High Rise Residential Units</td>
<td>Applies to the residential units in the building only.</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>Applies to buildings used for public or private film screenings. Gross Floor Area should</td>
</tr>
<tr>
<td>Building Type</td>
<td>Definition</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>include all space within the building(s), including seating areas, lobbies, concession stands, bathrooms, administrative/office space, mechanical rooms, storage areas, elevator shafts, and stairwells.</td>
</tr>
<tr>
<td>Office-Low Rise</td>
<td>Applies to facility spaces in buildings with four floors or fewer used for general office, professional, and administrative purposes. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc.</td>
</tr>
<tr>
<td>Office-Mid Rise</td>
<td>Applies to facility spaces in buildings with five to nine floors used for general office, professional, and administrative purposes. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc.</td>
</tr>
<tr>
<td>Office-High Rise</td>
<td>Applies to facility spaces in buildings with ten floors or more used for general office, professional, and administrative purposes. The total gross floor area should include all supporting functions such as kitchens used by staff, lobbies, atria, conference rooms and auditoria, fitness areas for staff, storage areas, stairways, elevator shafts, etc.</td>
</tr>
<tr>
<td>Religious Worship/Church</td>
<td>Applies to buildings that are used as places of worship. This includes churches, temples, mosques, synagogues, meetinghouses, or any other buildings that primarily function as a place of religious worship. Gross Floor Area should include all areas inside the building that includes the primary worship area, including food preparation, community rooms, classrooms, and supporting areas such as restrooms, storage areas, hallways, and elevator shafts.</td>
</tr>
<tr>
<td>Restaurant</td>
<td>Applies to a subcategory of Retail/Service space that is used to provide commercial food services to individual customers, and includes kitchen, dining, and common areas.</td>
</tr>
<tr>
<td>Retail/Service-Department store</td>
<td>Applies to facility space used to conduct the retail sale of consumer product goods. Stores must be at least 30,000 square feet and have an exterior entrance to the public. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, etc. Retail segments typically included under this definition are: Department Stores, Discount Stores, Supercenters, Warehouse Clubs, Drug Stores, Dollar Stores, Home Center/Hardware Stores, and Apparel/Hard Line Specialty Stores (e.g., books, clothing, office products, toys, home goods, electronics). Retail segments excluded under this definition are: Grocery, Convenience Stores, Automobile Dealerships, and Restaurants.</td>
</tr>
<tr>
<td>Retail/Service-Strip Mall</td>
<td>Applies to facility space used to conduct the retail sale of consumer product goods. Stores must less than 30,000 square feet and have an exterior entrance to the public. The total gross floor area should include all supporting functions such as kitchens and break rooms used by staff, storage areas, administrative areas, elevators, stairwells, etc. Retail segments excluded under this definition are: Grocery, Convenience Stores, Automobile Dealerships, and Restaurants.</td>
</tr>
<tr>
<td>Warehouse</td>
<td>Applies to unrefrigerated or refrigerated buildings that are used to store goods, manufactured products, merchandise or raw materials. The total gross floor area of Refrigerated Warehouses should include all temperature controlled area designed to store perishable goods or merchandise under refrigeration at temperatures below 50 degrees Fahrenheit. The total gross floor area of Unrefrigerated Warehouses should include space designed to store non-perishable goods and merchandise. Unrefrigerated warehouses also include distribution centers. The total gross floor area of refrigerated and unrefrigerated warehouses should include all supporting functions such as offices, lobbies, stairways, rest rooms, equipment storage areas, elevator shafts, etc. Existing atriums or areas with high ceilings should only include the base floor area that they occupy. The total gross floor area of refrigerated or unrefrigerated warehouse should not include outside loading bays or docks. Self-storage facilities, or facilities that rent individual storage units, are not eligible for a rating using the warehouse model.</td>
</tr>
</tbody>
</table>
Coincidence Factor (CF): Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis. Coincidence factors are provided for summer peak periods.

Commercial & Industrial: The market sector that includes measures that apply to any of the building types defined in this TRM, which includes multifamily common areas and public housing.

Connected Load: The maximum wattage of the equipment, under normal operating conditions.

Deemed Value: A value that has been assumed to be representative of the average condition of an input parameter.

Default Value: When a measure indicates that an input to a prescriptive saving algorithm may take on a range of values, an average value is also provided in many cases. This value is considered the default input to the algorithm, and should be used when the other alternatives listed in the measure are not applicable.

End-use Category: A general term used to describe the categories of equipment that provide a service to an individual or building. See Table 2.1.1 for a list of the end-use categories that are incorporated in this TRM.

Energy Efficiency: "Energy efficiency" means measures that reduce the amount of electricity or natural gas consumed in order to achieve a given end use. "Energy efficiency" includes voltage optimization measures that optimize the voltage at points on the electric distribution voltage system and thereby reduce electricity consumption by electric customers' end use devices. "Energy efficiency" also includes measures that reduce the total Btus of electricity, natural gas and other fuels needed to meet the end use or uses (20 ILCS 3855/1-10). For purposes of this Section, "energy efficiency" means measures that reduce the amount of energy required to achieve a given end use. "Energy efficiency" also includes measures that reduce the total Btus of electricity and natural gas needed to meet the end use or uses (220 ILCS 5/8-104(b)).

Equivalent Full Load Hours (EFLH): The equivalent hours that equipment would need to operate at its peak capacity in order to consume its estimated annual kWh consumption (annual kWh/connected kW) or therms.

High Efficiency: General term for technologies and processes that require less energy, water, or other inputs to operate.

Lifetime: The number of years (or hours) that the new high efficiency equipment is expected to function. These are generally based on engineering lives, but sometimes adjusted based on expectations about frequency of removal, remodeling or demolition. Two important distinctions fall under this definition; Effective Useful Life (EUL) and Remaining Useful Life (RUL).

EUL – EUL is based on the manufacturers rating of the effective useful life; how long the equipment will last. For example, a CFL that operates x hours per year will typically have an EUL of y. A house boiler may have a lifetime of 20 years but the EUL is only 15 years since after that time it may be operating at a non-efficient point. An estimate of the median number of years that the measures installed under a program are still in place and operable.

RUL – Applies to retrofit or replacement measures. For example, if an existing working refrigerator is replaced with a high efficiency unit, the RUL is an assumption of how many more years the existing unit would have lasted. As a general rule the RUL is usually assumed to be 1/3 of the EUL.

Load Factor (LF): The fraction of full load (wattage) for which the equipment is typically run.

Measure Cost: The incremental (for time of sale measures) or full cost (both capital and labor for retrofit measures) of implementing the High Efficiency equipment. See Section 3.8 Measure Incremental Cost Definition for full definition.

Measure Description: A detailed description of the technology and the criteria it must meet to be eligible as an energy efficient measure.

27 Measures that apply to the multifamily and public housing building types describe how to handle tenant versus master metered buildings.
Measure: An efficient technology or procedure that results in energy savings as compared to the baseline efficiency.

Residential: The market sector that includes measures that apply only to detached, residential buildings or duplexes.

Operation and Maintenance (O&M) Cost Adjustments: The dollar impact resulting from differences between baseline and efficient case Operation and Maintenance costs.

Operating Hours (HOURS): The annual hours that equipment is expected to operate.

Program: The mode of delivering a particular measure or set of measures to customers. See Table 2.4 for a list of program descriptions that are presently operating in Illinois.

Rating Period Factor (RPF): Percentages for defined times of the year that describe when energy savings will be realized for a specific measure.

Stakeholder Advisory Group (SAG): The Illinois Energy Efficiency Stakeholder Advisory Group (SAG) was first defined in the electric utilities’ first energy efficiency Plan Orders to include “... the Utility, DCEO, Staff, the Attorney General, BOMA and CUB and representation from a variety of interests, including residential consumers, business consumers, environmental and energy advocacy organizations, trades and local government... [and] a representative from the ARES (alternative retail electric supplier) community should be included.”28 A group of stakeholders who have an interest in Illinois’ energy efficiency programs and who meet regularly to share information and work toward consensus on various energy efficiency issues. The Utilities in Illinois have been directed by the ICC to work with the SAG on the development of a statewide TRM.

<table>
<thead>
<tr>
<th>Table 3.2: Degree-Day Zones and Values by Market Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Base Temp</td>
</tr>
</tbody>
</table>

3.5 Electrical Loadshapes (kWh)

Loadshapes are an integral part of the measure characterization and are used to divide energy savings into appropriate periods using Rating Period Factors (RPFs) such that each have variable avoided cost values allocated to them for the purpose of estimating cost effectiveness.

For the purposes of assigning energy savings (kWh) periods, the TRM TAC has agreed to use the industry standards for wholesale power market transactions as shown in the following table.

<table>
<thead>
<tr>
<th>Table 3.3: On and Off Peak Energy Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period Category</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Winter On-Peak Energy</td>
</tr>
</tbody>
</table>

Period Category | Period Definition (Central Prevailing Time)
---|---
Winter Off-Peak Energy | All other hours
Summer On-Peak Energy | 8AM - 11PM, weekdays, May – Sept, No NERC holidays
Summer Off-Peak Energy | All other hours

Loadshapes have been developed for each end-use by assigning Rating Period Factor percentages to each of the four periods above. Two methodologies were used:

1. Itron eShapes data for Missouri, reconciled to Illinois loads and provided by Ameren, were used to calculate the percentage of load in to the four categories above.

2. Where the Itron eShapes data did not provide a particular end-use or specific measure load profile, loadshapes that have been developed over many years by Efficiency Vermont and that have been reviewed by the Vermont Department of Public Service, were adjusted to match Illinois period definitions. Note – no weather sensitive loadshapes were based on this method. Any of these load profiles that relate to High Impact Measures should be an area of future evaluation.

The following pages provide the loadshape values for most measures provided in the TRM. To distinguish the source of the loadshape, they are color coded. Rows that are shaded in green are Efficiency Vermont loadshapes adjusted for Illinois periods. Rows that are unshaded and are left in white are Itron eShapes data provided by Ameren.

ComEd uses the DSMore™ (Integral Analytics DSMore™ Demand Side Management Option/Risk Evaluator) software to screen the efficiency measures for cost effectiveness. Since this tool requires a loadshape value for weekdays and weekends in each month (i.e., 24 inputs), the percentages for the four period categories above were calculated by weighting the proportion of weekdays/weekends in each month to the total within each period. The results of these calculations are also provided below.

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29 All loadshape information has been posted to the VEIC Sharepoint site, and is publically accessible through the Stakeholder Advisory Group’s web site. [http://www.ilsag.info/technical-reference-manual.html](http://www.ilsag.info/technical-reference-manual.html)
### Table 3.4: Loadshapes by Season

<table>
<thead>
<tr>
<th>Loadshape Reference Number</th>
<th>Winter Peak</th>
<th>Winter Off-peak</th>
<th>Summer Peak</th>
<th>Summer Off-peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oct-Apr, M-F, non-holiday, 8AM - 11PM</td>
<td>Oct-Apr, All other time</td>
<td>May-Sept, M-F, non-holiday, 8AM - 11PM</td>
<td>May- Sept, All other time</td>
</tr>
<tr>
<td>Residential Clothes Washer</td>
<td>R01</td>
<td>47.0%</td>
<td>11.1%</td>
<td>34.0%</td>
</tr>
<tr>
<td>Residential Dish Washer</td>
<td>R02</td>
<td>49.3%</td>
<td>8.7%</td>
<td>35.7%</td>
</tr>
<tr>
<td>Residential Electric DHW</td>
<td>R03</td>
<td>43.2%</td>
<td>20.6%</td>
<td>24.5%</td>
</tr>
<tr>
<td>Residential Freezer</td>
<td>R04</td>
<td>38.9%</td>
<td>16.4%</td>
<td>31.5%</td>
</tr>
<tr>
<td>Residential Refrigerator</td>
<td>R05</td>
<td>37.0%</td>
<td>18.1%</td>
<td>30.1%</td>
</tr>
<tr>
<td>Residential Indoor Lighting</td>
<td>R06</td>
<td>48.1%</td>
<td>15.5%</td>
<td>26.0%</td>
</tr>
<tr>
<td>Residential Outdoor Lighting</td>
<td>R07</td>
<td>18.0%</td>
<td>44.1%</td>
<td>9.4%</td>
</tr>
<tr>
<td>Residential Cooling</td>
<td>R08</td>
<td>4.1%</td>
<td>0.7%</td>
<td>71.3%</td>
</tr>
<tr>
<td>Residential Electric Space Heat</td>
<td>R09</td>
<td>57.8%</td>
<td>38.8%</td>
<td>1.7%</td>
</tr>
<tr>
<td>Residential Electric Heating and Cooling</td>
<td>R10</td>
<td>35.2%</td>
<td>22.8%</td>
<td>31.0%</td>
</tr>
<tr>
<td>Residential Ventilation</td>
<td>R11</td>
<td>25.8%</td>
<td>32.3%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Residential - Dehumidifier</td>
<td>R12</td>
<td>12.9%</td>
<td>16.2%</td>
<td>31.7%</td>
</tr>
<tr>
<td>Residential Standby Losses - Entertainment Center</td>
<td>R13</td>
<td>26.0%</td>
<td>32.5%</td>
<td>18.9%</td>
</tr>
<tr>
<td>Residential Standby Losses - Home Office</td>
<td>R14</td>
<td>23.9%</td>
<td>34.6%</td>
<td>17.0%</td>
</tr>
<tr>
<td>Residential Pool Pumps</td>
<td>R15</td>
<td>0%</td>
<td>0%</td>
<td>58.9%</td>
</tr>
<tr>
<td>Commercial Electric Cooking</td>
<td>C01</td>
<td>40.6%</td>
<td>18.2%</td>
<td>28.7%</td>
</tr>
<tr>
<td>Commercial Electric DHW</td>
<td>C02</td>
<td>40.5%</td>
<td>18.2%</td>
<td>28.5%</td>
</tr>
<tr>
<td>Commercial Cooling</td>
<td>C03</td>
<td>4.9%</td>
<td>0.8%</td>
<td>66.4%</td>
</tr>
<tr>
<td>Commercial Electric Heating</td>
<td>C04</td>
<td>53.5%</td>
<td>43.2%</td>
<td>1.9%</td>
</tr>
<tr>
<td>Commercial Electric Heating and Cooling</td>
<td>C05</td>
<td>19.4%</td>
<td>13.5%</td>
<td>47.1%</td>
</tr>
<tr>
<td>Commercial Indoor Lighting</td>
<td>C06</td>
<td>40.1%</td>
<td>18.6%</td>
<td>28.4%</td>
</tr>
<tr>
<td>Grocery/Conv. Store Indoor Lighting</td>
<td>C07</td>
<td>31.4%</td>
<td>26.4%</td>
<td>22.8%</td>
</tr>
<tr>
<td>Hospital Indoor Lighting</td>
<td>C08</td>
<td>29.1%</td>
<td>29.0%</td>
<td>21.0%</td>
</tr>
<tr>
<td>Office Indoor Lighting</td>
<td>C09</td>
<td>42.1%</td>
<td>16.0%</td>
<td>30.4%</td>
</tr>
<tr>
<td>Loadshape Reference Number</td>
<td>Winter Peak</td>
<td>Winter Off-peak</td>
<td>Summer Peak</td>
<td>Summer Off-peak</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------</td>
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</tr>
<tr>
<td>C10, Restaurant Indoor Lighting</td>
<td>32.1%</td>
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<td>23.4%</td>
<td>18.8%</td>
</tr>
<tr>
<td>C11, Retail Indoor Lighting</td>
<td>35.5%</td>
<td>22.3%</td>
<td>25.8%</td>
<td>16.3%</td>
</tr>
<tr>
<td>C12, Warehouse Indoor Lighting</td>
<td>39.4%</td>
<td>18.5%</td>
<td>28.6%</td>
<td>13.5%</td>
</tr>
<tr>
<td>C13, K-12 School Indoor Lighting</td>
<td>45.8%</td>
<td>22.6%</td>
<td>20.2%</td>
<td>11.4%</td>
</tr>
<tr>
<td>C14, Indust. 1-shift (8/5) (e.g., comp. air, lights)</td>
<td>50.5%</td>
<td>7.2%</td>
<td>37.0%</td>
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</tr>
<tr>
<td>C15, Indust. 2-shift (16/5) (e.g., comp. air, lights)</td>
<td>47.5%</td>
<td>10.2%</td>
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<td>7.4%</td>
</tr>
<tr>
<td>C16, Indust. 3-shift (24/5) (e.g., comp. air, lights)</td>
<td>34.8%</td>
<td>23.2%</td>
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<tr>
<td>C17, Indust. 4-shift (24/7) (e.g., comp. air, lights)</td>
<td>25.8%</td>
<td>32.3%</td>
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<td>23.0%</td>
</tr>
<tr>
<td>C18, Industrial Indoor Lighting</td>
<td>44.3%</td>
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<tr>
<td>C19, Industrial Outdoor Lighting</td>
<td>18.0%</td>
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<tr>
<td>C20, Commercial Outdoor Lighting</td>
<td>23.4%</td>
<td>35.3%</td>
<td>13.0%</td>
<td>28.3%</td>
</tr>
<tr>
<td>C21, Commercial Office Equipment</td>
<td>37.7%</td>
<td>20.9%</td>
<td>26.7%</td>
<td>14.7%</td>
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<tr>
<td>C22, Commercial Refrigeration</td>
<td>38.5%</td>
<td>20.6%</td>
<td>26.7%</td>
<td>14.2%</td>
</tr>
<tr>
<td>C23, Commercial Ventilation</td>
<td>38.1%</td>
<td>20.6%</td>
<td>29.7%</td>
<td>11.6%</td>
</tr>
<tr>
<td>C24, Traffic Signal - Red Balls, always changing or flashing</td>
<td>25.8%</td>
<td>32.3%</td>
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</tr>
<tr>
<td>C25, Traffic Signal - Red Balls, changing day, off night</td>
<td>37.0%</td>
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</tr>
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<td>C26, Traffic Signal - Green Balls, always changing</td>
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<td>C27, Traffic Signal - Green Balls, changing day, off night</td>
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</tr>
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<td>C28, Traffic Signal - Red Arrows</td>
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<td>C29, Traffic Signal - Green Arrows</td>
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<td>C30, Traffic Signal - Flashing Yellows</td>
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<tr>
<td>C31, Traffic Signal - “Hand” Don’t Walk Signal</td>
<td>25.8%</td>
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<tr>
<td>C32, Traffic Signal - “Man” Walk Signal</td>
<td>25.8%</td>
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</tr>
<tr>
<td>C33, Traffic Signal - Bi-Modal Walk/Don’t Walk</td>
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<tr>
<td>C34, Industrial Motor</td>
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<td>C36, HVAC Pump Motor (heating)</td>
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### Table: Loadshape Reference Number

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<th>Winter Peak</th>
<th>Winter Off-peak</th>
<th>Summer Peak</th>
<th>Summer Off-peak</th>
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<td>HVAC Pump Motor (cooling)</td>
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<tr>
<td>HVAC Pump Motor (unknown use)</td>
<td>C38</td>
<td>23.2%</td>
<td>29.2%</td>
<td>21.4%</td>
</tr>
<tr>
<td>VFD - Supply fans &lt;10 HP</td>
<td>C39</td>
<td>38.8%</td>
<td>16.1%</td>
<td>28.4%</td>
</tr>
<tr>
<td>VFD - Return fans &lt;10 HP</td>
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<td>38.8%</td>
<td>16.1%</td>
<td>28.4%</td>
</tr>
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<td>VFD - Exhaust fans &lt;10 HP</td>
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</tr>
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<td>VFD - Boiler feedwater pumps &lt;10 HP</td>
<td>C42</td>
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</tr>
<tr>
<td>VFD - Chilled water pumps &lt;10 HP</td>
<td>C43</td>
<td>11.2%</td>
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<tr>
<td>Refrigeration Economizer</td>
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<td>Evaporator Fan Control</td>
<td>C46</td>
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<tr>
<td>Standby Losses - Commercial Office</td>
<td>C47</td>
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</tr>
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<td>Engine Block Heater Timer</td>
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</tr>
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<td>Door Heater Control</td>
<td>C51</td>
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<tr>
<td>Beverage and Snack Machine Controls</td>
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<td>10.0%</td>
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<td>Religious Indoor Lighting</td>
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### Table 3.5: Loadshapes by Month and Day of Week

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M-F</td>
<td>S-S</td>
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<td>S-S</td>
<td>M-F</td>
<td>S-S</td>
<td>M-F</td>
<td>S-S</td>
</tr>
<tr>
<td>Residential Clothes</td>
<td>R01</td>
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<td>1.5%</td>
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<td>1.7%</td>
<td>6.7%</td>
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<tr>
<td>Washer R02</td>
<td>7.3%</td>
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<td>1.4%</td>
<td>7.1%</td>
<td>1.2%</td>
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<tr>
<td>Residential Dish</td>
<td>R03</td>
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<td>2.9%</td>
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<td>2.7%</td>
<td>6.1%</td>
<td>3.3%</td>
<td>6.2%</td>
<td>2.8%</td>
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<td>2.3%</td>
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<tr>
<td>Washer R04</td>
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<td>2.4%</td>
<td>5.2%</td>
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<td>2.5%</td>
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<tr>
<td>Refrigerator</td>
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<td>2.4%</td>
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<td>2.1%</td>
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</tr>
<tr>
<td>Residential Outdoor</td>
<td>R07</td>
<td>2.7%</td>
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<td>2.4%</td>
<td>5.9%</td>
<td>2.6%</td>
<td>7.0%</td>
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</tr>
<tr>
<td>Lighting</td>
<td>R08</td>
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<tr>
<td>Residential</td>
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<td>5.8%</td>
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</tr>
<tr>
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<td>3.7%</td>
<td>4.2%</td>
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<td>4.3%</td>
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<td>2.1%</td>
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<td>4.3%</td>
<td>3.4%</td>
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<td>4.0%</td>
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<td>3.6%</td>
<td>4.2%</td>
<td>3.8%</td>
<td>5.0%</td>
<td>3.8%</td>
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<td>3.9%</td>
<td>4.5%</td>
<td>3.6%</td>
<td>4.7%</td>
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3.6 Summer Peak Period Definition (kW)

To estimate the impact that an efficiency measure has on a utility’s system peak, the peak itself needs to be defined. Illinois spans two different electrical control areas, the Pennsylvania – Jersey – Maryland (PJM) and the Midwest Independent System Operators (MISO). As a result, there is some disparity in the peak definition across the state. However, only PJM has a forward capacity market where an efficiency program can potentially participate. Because ComEd is part of the PJM control area, their definition of summer peak is being applied statewide in this TRM.

Because Illinois is a summer peaking state, only the summer peak period is defined for the purpose of this TRM. The coincident summer peak period is defined as 1:00-5:00 PM Central Prevailing Time on non-holiday weekdays, June through August.

Summer peak coincidence factors can be found within each measure characterization. The source is provided and is based upon evaluation results, analysis of load shape data (e.g., the Itron eShapes data provided by Ameren), or through a calculation using stated assumptions.

For measures that are not weather-sensitive, the summer peak coincidence factor is estimated whenever possible as the average of savings within the peak period defined above. For weather sensitive measures such as cooling, the summer peak coincidence factor is provided in two different ways. The first method is to estimate demand savings during the utility’s peak hour (as provided by Ameren). This is likely to be the most indicative of actual peak benefits. The second way represents the average savings over the summer peak period, consistent with the non-weather sensitive end uses, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

3.7 Heating and Cooling Degree-Day Data

Many measures are weather sensitive. Because there is a range of climactic conditions across the state, VEIC engaged the Utilities to provide their preferences for what airports and cities are the best proxies for the weather in their service territories. The result of this engagement is in the table below. All of the data represents 30-year normals from the National Climactic Data Center (NCDC). Note that the base temperature for the calculation of heating degree-days in this document does not follow the historical 65°F degree base temperature convention. Instead VEIC used several different temperatures in this TRM to more accurately reflect the outdoor temperature when a heating or cooling system turns on.

Residential heating is based on 60°F, in accordance with regression analysis of heating fuel use and weather by state by the Pacific Northwest National Laboratory. Residential cooling is based on 65°F in agreement with a field study in Wisconsin. These are lower than typical thermostat set points because internal gains such as appliances, lighting, and people provide some heating. In C&I settings, internal gains are often much higher; the base temperatures for both heating and cooling is 55°F. Custom degree-days with building specific base temperatures are recommended for large C&I projects.

30-year normals have been used instead of Typical Meteorological Year (TMY) data due to the fact that few of the measures in the TRM are significantly affected by solar insolation, which is one of the primary benefits of using the TMY approach.


Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p. 32 (amended in 2010).

This value is based upon experience, and it is preferable to use building-specific base temperatures when available.
Table 3.6: Degree-Day Zones and Values by Market Sector

<table>
<thead>
<tr>
<th>Zone</th>
<th>Residential HDD</th>
<th>Residential CDD</th>
<th>C&amp;I HDD</th>
<th>C&amp;I CDD</th>
<th>Weather Station / City</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>5,352</td>
<td>820</td>
<td>4,272</td>
<td>2,173</td>
<td>Rockford AP / Rockford</td>
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<tr>
<td>2</td>
<td>5,113</td>
<td>842</td>
<td>4,029</td>
<td>3,357</td>
<td>Chicago O'Hare AP / Chicago</td>
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<tr>
<td>3</td>
<td>4,379</td>
<td>1,108</td>
<td>3,406</td>
<td>2,666</td>
<td>Springfield #2 / Springfield</td>
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<tr>
<td>4</td>
<td>3,378</td>
<td>1,570</td>
<td>2,515</td>
<td>3,090</td>
<td>Belleville SIU RSCH / Belleville</td>
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<tr>
<td>5</td>
<td>3,438</td>
<td>1,370</td>
<td>2,546</td>
<td>2,182</td>
<td>Carbondale Southern IL AP / Marion</td>
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<tr>
<td>Average</td>
<td>4,860</td>
<td>947</td>
<td>3,812</td>
<td>3,051</td>
<td>Weighted by occupied housing units</td>
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<tr>
<td>Base Temp</td>
<td>60F</td>
<td>65F</td>
<td>55F</td>
<td>55F</td>
<td>30 year climate normals, 1981-2010</td>
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</table>

This table assigns each of the proxy cities to one of five climate zones. The following graphics from the Illinois State Water Survey show isobars (lines of equal degree-days) and we have color-coded the counties in each of these graphics using those isobars as a dividing line. Using this approach, the state divides into five cooling degree-day zones and five heating degree-day zones. Note that although the heating and cooling degree-day maps are similar, they are not the same, and the result is that there are a total of 10 climate zones in the state. The counties are listed in the tables following the figures for ease of reference.
Figure 3.1: Cooling Degree-Day Zones by County
Figure 3.2: Heating Degree-Day Zones by County
### Table 3.7: Heating Degree-Day Zones by County

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### Table 3.8: Cooling Degree-day Zones by County

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3.8 Measure Incremental Cost Definition

Incremental Costs means the difference between the cost of the efficient Measure and the cost of the most relevant baseline measure that would have been installed (if any) in the absence of the efficiency Program. Installation costs (material and labor) and Operations and Maintenance (O&M) costs shall be included if there is a difference between the efficient Measure and the baseline measure. In cases where the efficient Measure has a significantly shorter or longer life than the relevant baseline measure (e.g., LEDs versus halogens), the avoided baseline replacement measure costs should be accounted for in the TRC analysis. The Customer’s value of service lost, the Customer’s value of their lost amenity, and the Customer’s transaction costs shall be included in the TRC analysis where a reasonable estimate or proxy of such costs can be easily obtained (e.g., Program Administrator payment to a Customer to reduce load during a demand response event, Program Administrator payment to a Customer as an inducement to give up duplicative functioning equipment). This Incremental Cost input in the TRC analysis is not reduced by the amount of any Incentives (any Financial Incentives Paid to Customers or Incentives Paid to Third Parties by a Program Administrator that is intended to reduce the price of the efficient Measure to the Customer). Incremental Cost calculations will vary depending on the type of efficient Measure being implemented, as outlined in the examples provided below and as set forth in the IL-TRM.

Examples of Incremental Cost calculations include:

a. The Incremental Cost for an efficient Measure that is installed in new construction or is being purchased at the time of natural installation, investment, or replacement is the additional cost incurred to purchase an efficient Measure over and above the cost of the baseline/standard (i.e., less efficient) measure (including any incremental installation, replacement, or O&M costs if there is a difference between the efficient Measure and baseline measure).

b. For a retrofit Measure where the efficiency Program caused the Customer to update their existing equipment, facility, or processes (e.g., air sealing, insulation, tank wrap, controls), where the Customer would not have otherwise made a purchase, the appropriate baseline is zero expenditure, and the Incremental Cost is the full cost of the new retrofit Measure (including installation costs).

c. For the early replacement of a functioning measure with a new efficient Measure, where the Customer would not have otherwise made a purchase for a number of years, the appropriate baseline is a dual baseline that begins as the existing measure and shifts to the new standard measure after the expected remaining useful life of the existing measure ends. Thus, the Incremental Cost is the full cost of the new efficient Measure (including installation costs) being purchased to replace a still-functioning measure less the present value of the assumed deferred replacement cost of replacing the existing measure with a new baseline measure at the end of the existing measure’s life (described in section 3.9). This deferred credit may not be necessary when the lifetime of the measure is short, the costs are very low, or for other reasons (e.g., certain Direct Install Measures, Measures provided in Kits to Customers).

d. For study-based services (e.g., facility energy audits, energy surveys, energy assessments, retro-commissioning) that are truly necessary for a Customer to implement efficient Measures, as opposed to being principally intended to be a form of marketing, the Incremental Cost is the full cost of the study-based service. Even if the study-based service is performed entirely by a Program Administrator’s implementation contractor, the full cost of the study-based service charged by the implementation contractor is the Incremental Cost, because this is assumed to be the cost of the study-based service that would have been incurred by the Customer if the Customer were to have the study-based service performed in the absence of the efficiency Program. If the Customer implements efficient Measures as a result of the study-based service provided by the efficiency Program, the Incremental Cost for those efficient Measures should also be classified as Incremental Costs in the TRC analysis.

e. For the early retirement of duplicative functioning equipment before its expected life is over (e.g., appliance recycling Programs), the Incremental Costs are composed of the Customer’s value placed on their lost amenity, any Customer transaction costs, and the pickup and recycling cost. The Incremental Costs include the actual cost of the pickup and recycling of the equipment (often paid for by a Program Administrator to
an implementation contractor) because this is assumed to be the cost of recycling the equipment that would have been incurred by the Customer if the Customer were to recycle the equipment on their own in the absence of the efficiency Program. The payment a Program Administrator makes to the Customer serves as a proxy for the value the Customer places on their lost amenity and any Customer transaction costs.

3.9 Discount Rates, Inflation Rates and O&M Costs

The Illinois Utilities utilize screening tools that apply an appropriate discount rate to any future costs or benefits. The societal discount rate, required for use by all electric utilities, is defined as a nominal discount rate of 2.38%, or a real (inflation-adjusted) discount rate of 0.46%\(^{34}\).

Where a future cost is provided within the TRM (e.g. in early replacement measures where a deferred baseline replacement cost is provided) and the future cost has been adjusted using an inflation rate (based upon the 20-year Treasury yield of 1.91\(^{35}\)), the nominal discount rate should be used to discount to the present value. Where future costs have not been adjusted for inflation, the real discount rate should be used to discount to present value.

Some measures specify an operations and maintenance (O&M) parameter that describes the incremental O&M cost savings that can be expected over the measure’s lifetime. For most measures the TRM does not specify the NPV of the O&M costs. Instead, the necessary information required to calculate the NPV is included. An example is provided below:

| Baseline Case: | O&M costs equal $150 every two years. |
| Efficient Case: | O&M costs equal $50 every five years. |

Given this information, the incremental O&M costs can be determined by discounting the cash flows in the Baseline Case and the Efficient Case separately using the real discount rate.

For a select few measures that include baseline shifts that result in multiple component costs and lifetimes over the lifetime of the measure, this standard method cannot be used. In only these cases, the O&M costs are presented both as Annual Levelized equivalent cost (i.e., the annual payment that results in an equivalent NPV to the actual stream of O&M costs) and as NPVs using a real societal discount rate of 0.46%.

\(^{34}\) Based on the current 10 year Treasury bond yield rates, as of January 2017. The 10 year rates are utilized to be consistent with the average measure life of the measures specified within this TRM.

\(^{35}\) Established for use in the TRM in late 2015.
3.10 Interactive Effects

The TRM presents engineering equations for most measures. This approach is desirable because it conveys information clearly and transparently, and is widely accepted in the industry. Unlike simulation model results, engineering equations also provide flexibility and the opportunity for users to substitute local, specific information for specific input values. Furthermore, the parameters can be changed in TRM updates to be applied in future years as better information becomes available.

One limitation is that some interactive effects between measures are not automatically captured. Because we cannot know what measures will be implemented at the same time with the same customer, we cannot always capture the interactions between multiple measures within individual measure characterizations. However, interactive effects with different end-uses are included in individual measure characterizations whenever possible. For instance, waste heat factors are included in the lighting characterizations to capture the interaction between more-efficient lighting measures and the amount of heating and/or cooling that is subsequently needed in the building.

By contrast, no effort is made to account for interactive effects between an efficient air conditioning measure and an efficient lighting measure, because it is impossible to know the specifics of the other measure in advance of its installation. For custom measures and projects where a bundle of measures is being implemented at the same time, these kinds of interactive effects should be estimated.

---

36 For more information, please refer to the document, “Dealing with Interactive Effects During Measure Characterization” Memo to the Stakeholder Advisory Group dated 12/13/11. 
http://portal.veic.org/projects/illinoistrm/Shared%20Documents/Memos/Interactive_Effects_Memo_121311.docx

Version 6.0

Volume 2: Commercial and Industrial Measures

FINAL

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VOLUME 3: RESIDENTIAL MEASURES

VOLUME 4: CROSS CUTTING MEASURES AND ATTACHMENTS
Volume 2: Commercial and Industrial Measures

4.1 Agricultural End Use

4.1.1 Engine Block Timer for Agricultural Equipment

DESCRIPTION
The measure is a plug-in timer that is activated below a specific outdoor temperature to control an engine block heater in agricultural equipment. Engine block heaters are typically used during cold weather to pre-warm an engine prior to start, for convenience heaters are typically plugged in considerably longer than necessary to improve startup performance. A timer allows a user to preset the heater to come on for only the amount of time necessary to pre-warm the engine block, reducing unnecessary run time even if the baseline equipment has an engine block temperature sensor.

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

DEFINITION OF EFFICIENT EQUIPMENT
The efficient measure is an engine block heater operated by an outdoor plug-in timer (15 amp or greater) that turns on the heater only when the outdoor temperature is below 25 °F.

DEFINITION OF BASELINE EQUIPMENT
The baseline scenario is an engine block heater that is manually plugged in by the farmer to facilitate equipment startup at a later time.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life if assumed to be 3 years.

DEEMED MEASURE COST
The incremental cost per installed plug-in timer is $10.19.

COINCIDENCE FACTOR
Engine block timers only operate in the winter so the summer peak demand savings is zero.

Calculation of Savings

Electric Energy Savings

\[ \Delta \text{kWh} = \text{ISR} \times \text{Use Season} \times \% \text{Days} \times \text{HrSave/Day} \times \text{kW}_{\text{heater}} \times \text{ParaLd} \]

= 78.39% \times 87 \text{ days} \times 84.23\% \times 7.765 \text{ Hr/Day} \times 1.5 \text{ kW} \times 5.46 \text{ kWh}

= 664 \text{ kWh}

1Equipment life is expected to be longer, but measure life is more conservative to account for possible attrition in use over time.

2Based on bulk pricing reported by EnSave, which administers the rebate in Vermont.
SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: RS-APL-ESDH-V01-120601

REVIEW DEADLINE: 1/1/2019
4.1.2 High Volume Low Speed Fans

DESCRIPTION

The measure applies to 20-24 foot diameter horizontally mounted ceiling high volume low speed (HVLS) fans that are replacing multiple non HVLS fans that have reached the end of useful life in agricultural applications.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be classified as HVLS and have a VFD³.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be multiple non HVLS existing fans that have reached the end of its useful life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 10 years⁴.

DEEMED MEASURE COST

The incremental capital cost for the fans are as follows⁵:

<table>
<thead>
<tr>
<th>Fan Diameter Size (feet)</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>$4150</td>
</tr>
<tr>
<td>22</td>
<td>$4180</td>
</tr>
<tr>
<td>24</td>
<td>$4225</td>
</tr>
</tbody>
</table>

LOADSHAPE

Loadshape C34 - Industrial Motor

COINCIDENCE FACTOR

The measure has deemed kW savings therefore a coincidence factor is not applied.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS ⁶

The annual electric savings from this measure are deemed values depending on fan size and apply to all building types:

<table>
<thead>
<tr>
<th>Fan Diameter Size (feet)</th>
<th>kWh Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>6577</td>
</tr>
</tbody>
</table>

⁴ Ibid.
⁵ Ibid.
⁶ Ibid.
### Fan Diameter Size (feet) kWh Savings

<table>
<thead>
<tr>
<th>Fan Diameter Size (feet)</th>
<th>kWh Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>8543</td>
</tr>
<tr>
<td>24</td>
<td>10018</td>
</tr>
</tbody>
</table>

#### Summer Coincident Peak Demand Savings

The annual kW savings from this measure are deemed values depending on fan size and apply to all building types:

<table>
<thead>
<tr>
<th>Fan Diameter Size (feet)</th>
<th>kW Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2.4</td>
</tr>
<tr>
<td>22</td>
<td>3.1</td>
</tr>
<tr>
<td>24</td>
<td>3.7</td>
</tr>
</tbody>
</table>

**Natural Gas Energy Savings**

N/A

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: CI-AGE-HVSF-V01-120601**

**Review Deadline: 1/1/2019**

---

7 Ibid.
4.1.3 High Speed Fans

DESCRIPTION

The measure applies to high speed exhaust, ventilation and circulation fans that are replacing an existing unit that reached the end of its useful life in agricultural applications.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be diffuser equipped and meet the following criteria:

<table>
<thead>
<tr>
<th>Diameter of Fan (inches)</th>
<th>Minimum Efficiency for Exhaust &amp; Ventilation Fans</th>
<th>Minimum Efficiency for Circulation Fans</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 through 35</td>
<td>14.0 cfm/W at 0.10 static pressure</td>
<td>12.5 lbf/kW</td>
</tr>
<tr>
<td>36 through 47</td>
<td>17.1 cfm/W at 0.10 static pressure</td>
<td>18.2 lbf/kW</td>
</tr>
<tr>
<td>48 through 71</td>
<td>20.3 cfm/W at 0.10 static pressure</td>
<td>23.0 lbf/kW</td>
</tr>
</tbody>
</table>

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline condition is assumed to be an existing fan that reached the end of its useful life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 7 years.

DEEMED MEASURE COST

The incremental capital cost for all fan sizes is $150.

LOADSHAPE

Loadshape C34 - Industrial Motor

COINCIDENCE FACTOR

The measure has deemed kW savings therefore a coincidence factor is not applied.

ALGORITHM

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

The annual electric savings from this measure are deemed values depending on fan size and apply to all building types:

---

9 Ibid.
10 Ibid.
11 Ibid.
### Diameter of Fan (inches) kWh

- 24 through 35 372
- 36 through 47 625
- 48 through 71 1122

### Summer Coincident Peak Demand Savings\(^\text{12}\)

The annual kW savings from this measure are deemed values depending on fan size and apply to all building types:

<table>
<thead>
<tr>
<th>Diameter of Fan (inches)</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 through 35</td>
<td>0.118</td>
</tr>
<tr>
<td>36 through 47</td>
<td>0.198</td>
</tr>
<tr>
<td>48 through 71</td>
<td>0.356</td>
</tr>
</tbody>
</table>

### Natural Gas Energy Savings

N/A

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: CI-AGE-HSF_-V01-120601

### Review Deadline: 1/1/2019

\(^{12}\) Ibid.
4.1.4 Live Stock Waterer

DESCRIPTION
This measure applies to the replacement of electric open waterers with sinking or floating water heaters with equivalent herd size watering capacity of the old unit.

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

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, the efficient equipment is assumed to an electrically heated thermally insulated waterer with minimum 2 inches of insulation. A thermostat is required on unit with heating element greater than or equal to 250 watts\textsuperscript{13}.

DEFINITION OF BASELINE EQUIPMENT
In order for this characterization to apply, the baseline equipment is assumed to be an electric open waterer with sinking or floating water heaters that have reached the end of useful life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 10 years\textsuperscript{14}.

DEEMED MEASURE COST
The incremental capital cost for the waters are $787.50:\textsuperscript{15}

LOADSHAPE
Loadshape C04 - Non-Residential Electric Heating

COINCIDENCE FACTOR
The measure has deemed kW savings therefore a coincidence factor is not applied

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS \textsuperscript{16}
The annual electric savings from this measure is a deemed value and assumed to be 1592.85 kWh.

SUMMER COINCIDENT PEAK DEMAND SAVINGS
The annual kW savings from this measure is a deemed value and assumed to be 0.525 kW. \textsuperscript{17}

\textsuperscript{13} Act on Energy Commercial Technical Reference Manual No. 2010-4
\textsuperscript{14} Ibid.
\textsuperscript{15} Ibid.
\textsuperscript{16} Ibid.
\textsuperscript{17} Ibid.
NATURAL GAS ENERGY SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-AGE-LSW1-V01-120601

REVIEW DEADLINE: 6/1/2018
4.2 Food Service Equipment End Use

4.2.1 Combination Oven

**DESCRIPTION**

This measure applies to both natural gas fired and electric high efficiency combination convection and steam ovens installed in a commercial kitchen.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure, the installed equipment must be a new natural gas or electric combination oven meeting the ENERGY STAR idle rate and cooking efficiency requirements as specified below.\(^\text{18}\)

**ENERGY STAR Requirements (Version 2.1, Effective January 1, 2014)**

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Operation</th>
<th>Idle Rate (Btu/h for Gas, kW for Electric)</th>
<th>Cooking-Energy Efficiency, (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>Steam Mode</td>
<td>≤ 200P+6,511</td>
<td>≥ 41</td>
</tr>
<tr>
<td></td>
<td>Convection Mode</td>
<td>≤ 150P+5,425</td>
<td>≥ 56</td>
</tr>
<tr>
<td>Electric</td>
<td>Steam Mode</td>
<td>≤ 0.133P+0.6400</td>
<td>≥ 55</td>
</tr>
<tr>
<td></td>
<td>Convection Mode</td>
<td>≤ 0.080P+0.4989</td>
<td>≥ 76</td>
</tr>
</tbody>
</table>

Note: \(P\) = Pan capacity as defined in Section 1.5, of the Commercial Ovens Program Requirements Version 2.1\(^\text{19}\)

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a natural gas or electric combination oven that is not ENERGY STAR certified.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years.\(^\text{20}\)

**DEEMED MEASURE COST**

The costs vary based on the efficiency and make of the equipment. Actual costs should be used.

**LOADSHAPE**

Loadshape C01 - Commercial Electric Cooking

**COINCIDENCE FACTOR**

Summer Peak Coincidence Factor for measure is provided below for different building type\(^\text{21}\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
</tbody>
</table>

---

\(^{18}\) ENERGY STAR Commercial Ovens Key Product Criteria http://www.energystar.gov/index.cfm?c=ovens.pr_crit_comm_ovens

\(^{19}\) Pan capacity is defined as the number of steam table pans the combination oven is able to accommodate as per the ASTM F-1495-05 standard specification. http://www.energystar.gov/products/specs/system/files/Commercial%20Ovens%20Program%20Requirements%20V2%201.pdf?965d-c5ec&3b06-d2f5


Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

The algorithm below applies to electric combination ovens only.\(^{22}\)

$$\Delta \text{kWh} = (\Delta \text{CookingEnergy}^{\text{ConvElec}} + \Delta \text{CookingEnergy}^{\text{SteamElec}} + \Delta \text{IdleEnergy}^{\text{ConvElec}} + \Delta \text{IdleEnergy}^{\text{SteamElec}}) \times \text{Days} / 1,000$$

Where:

- \(\Delta \text{CookingEnergy}^{\text{ConvElec}}\) = Change in total daily cooking energy consumed by electric oven in convection mode
  
  $$= \text{LB}^{\text{Elec}} \times (\text{EFOOD}^{\text{ConvElec}} / \text{ElecEFF}^{\text{ConvBase}} - \text{EFOOD}^{\text{ConvElec}} / \text{ElecEFF}^{\text{ConvEE}}) \times \%^{\text{Conv}}$$

- \(\Delta \text{CookingEnergy}^{\text{SteamElec}}\) = Change in total daily cooking energy consumed by electric oven in steam mode
  
  $$= \text{LB}^{\text{Elec}} \times (\text{EFOOD}^{\text{SteamElec}} / \text{ElecEFF}^{\text{SteamBase}} - \text{EFOOD}^{\text{SteamElec}} / \text{ElecEFF}^{\text{SteamEE}}) \times \%^{\text{Steam}}$$

- \(\Delta \text{IdleEnergy}^{\text{ConvElec}}\) = Change in total daily idle energy consumed by electric oven in convection mode
  
  $$= \left[\left(\text{ElecIDLE}^{\text{ConvBase}} \times \left(\text{HOURS} - \text{LB}^{\text{Elec}} / \text{ElecPC}^{\text{ConvBase}}\right) \times \%^{\text{Conv}}\right) - \left(\text{ElecIDLE}^{\text{ConvEE}} \times \left(\text{HOURS} - \text{LB}^{\text{Elec}} / \text{ElecPC}^{\text{ConvEE}}\right) \times \%^{\text{Conv}}\right)\right]$$

- \(\Delta \text{IdleEnergy}^{\text{SteamElec}}\) = Change in total daily idle energy consumed by electric oven in convection mode
  
  $$= \left[\left(\text{ElecIDLE}^{\text{SteamBase}} \times \left(\text{HOURS} - \text{LB}^{\text{Elec}} / \text{ElecPC}^{\text{SteamBase}}\right) \times \%^{\text{Steam}}\right) - \left(\text{ElecIDLE}^{\text{SteamEE}} \times \left(\text{HOURS} - \text{LB}^{\text{Elec}} / \text{ElecPC}^{\text{SteamEE}}\right) \times \%^{\text{Steam}}\right)\right]$$

Where:

- \(\text{LB}^{\text{Elec}}\) = Estimated mass of food cooked per day for electric oven (lbs/day)
  
  - Custom, or if unknown, use 200 lbs (if \(P < 15\)) or 250 lbs (if \(P \geq 15\))

- \(\text{EFOOD}^{\text{ConvElec}}\) = Energy absorbed by food product for electric oven in convection mode
  
  - Custom or if unknown, use 73.2 Wh/lb

- \(\text{ElecEFF}\) = Cooking energy efficiency of electric oven
  
  - Custom or if unknown, use values from table below

---

\(^{22}\) Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator

%Conv = Percentage of time in convection mode
= Custom or if unknown, use 50%

EFOOD_{Steam,Elec} = Energy absorbed by food product for electric oven in steam mode
= Custom or if known, use 30.8 Wh/lb

%_{steam} = Percentage of time in steam mode
= 1 - %_{conv}

ElecIDLE_{Base} = Idle energy rate (W) of baseline electric oven
= Custom or if unknown, use values from table below

<table>
<thead>
<tr>
<th>Pan Capacity</th>
<th>Convection Mode (ElecIDLE_{Conv,Base})</th>
<th>Steam Mode (ElecIDLE_{Steam,Base})</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>1,320</td>
<td>5,260</td>
</tr>
<tr>
<td>&gt;= 15</td>
<td>2,280</td>
<td>8,710</td>
</tr>
</tbody>
</table>

HOURS = Average daily hours of operation
= Custom or if unknown, use 12 hours

ElecPC_{Base} = Production capacity (lbs/hr) of baseline electric oven
= Custom or if unknown, use values from table below

<table>
<thead>
<tr>
<th>Pan Capacity</th>
<th>Convection Mode (ElecPC_{Conv,Base})</th>
<th>Steam Mode (ElecPC_{Steam,Base})</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>79</td>
<td>126</td>
</tr>
<tr>
<td>&gt;= 15</td>
<td>166</td>
<td>295</td>
</tr>
</tbody>
</table>

ElecIDLE_{Conv,EE} = Idle energy rate of ENERGY STAR electric oven in convection mode
= (0.08*P + 0.4989)*1000

ElecPC_{EE} = Production capacity (lbs/hr) of ENERGY STAR electric oven
= Custom or if unknown, use values from table below

<table>
<thead>
<tr>
<th>Pan Capacity</th>
<th>Convection Mode (ElecPC_{Conv,EE})</th>
<th>Steam Mode (ElecPC_{Steam,EE})</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>119</td>
<td>177</td>
</tr>
<tr>
<td>&gt;= 15</td>
<td>201</td>
<td>349</td>
</tr>
</tbody>
</table>

ElecIDLE_{Steam,EE} = Idle energy rate of ENERGY STAR electric oven in steam mode
= (0.133* P + 0.64)*1000

Days = Days of operation per year
= Custom or if unknown, use 365 days per year

1,000 = Wh to kWh conversion factor
EXAMPLE

For example, a 10-pan capacity electric combination oven would save:

\[ \Delta kWh = \frac{(\Delta \text{CookingEnergy}_{\text{ConvElec}} + \Delta \text{CookingEnergy}_{\text{SteamElec}} + \Delta \text{IdleEnergy}_{\text{ConvElec}} + \Delta \text{IdleEnergy}_{\text{SteamElec}}) \times \text{Days}}{1,000} \]

\[ \Delta \text{CookingEnergy}_{\text{ConvElec}} = 200 \times (73.2 / 0.72 - 73.2 / 0.76) \times 0.50 = 535 \text{ Wh} \]

\[ \Delta \text{CookingEnergy}_{\text{SteamElec}} = 200 \times (30.8 / 0.49 - 30.8 / 0.55) \times (1 - 0.50) = 686 \text{ Wh} \]

\[ \Delta \text{IdleEnergy}_{\text{ConvElec}} = [(1,320 \times ((12 - 200/79) \times 0.50)) - (1,299 \times ((12 - 200/119) \times 0.50))] = -453 \text{ Wh} \]

\[ \Delta \text{IdleEnergy}_{\text{SteamElec}} = [(5,260 \times ((12 - 200/126) \times (1 - 0.50))) - (1,970 \times ((12 - 200/177) \times (1 - 0.50)))] = 16,678 \text{ Wh} \]

\[ \Delta kWh = (535 + 686 - 453 + 16,678) \times 365 / 1,000 = 6,368 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \frac{\Delta kWh}{\text{ (HOURS} \times \text{ DAYS})} \times \text{CF} \]

Where:

- \( \text{CF} \) = Summer peak coincidence factor is dependent on building type\(^{23}\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
</tbody>
</table>

All other variables as defined above.

**EXAMPLE**

For example, a 10-pan capacity electric combination oven in a Full Service Limited Menu restaurant would save:

\[ \Delta kW = \frac{\Delta kWh}{\text{ (HOURS} \times \text{ DAYS})} \times \text{CF} \]

\[ = \frac{6,368 \times (12 \times 365)}{1,000} \times 0.51 = 0.74 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

The algorithm below applies to natural gas combination ovens only.  

\[
\Delta \text{Therms} = (\Delta \text{CookingEnergy}_{\text{ConvGas}} + \Delta \text{CookingEnergy}_{\text{SteamGas}} + \Delta \text{IdleEnergy}_{\text{ConvGas}} + \Delta \text{IdleEnergy}_{\text{SteamGas}}) \times \text{Days} / 100,000
\]

Where:

\[\Delta \text{CookingEnergy}_{\text{ConvGas}} = \text{Change in total daily cooking energy consumed by gas oven in convection mode} = \text{LB}_{\text{Gas}} \times \left( \frac{\text{EFOOD}_{\text{ConvGas}}}{\text{GasEFF}_{\text{ConvBase}}} - \frac{\text{EFOOD}_{\text{ConvGas}}}{\text{GasEFF}_{\text{ConvEE}}} \right) \times \%_{\text{Conv}}\]

\[\Delta \text{CookingEnergy}_{\text{SteamGas}} = \text{Change in total daily cooking energy consumed by gas oven in steam mode} = \text{LB}_{\text{Gas}} \times \left( \frac{\text{EFOOD}_{\text{SteamGas}}}{\text{GasEFF}_{\text{SteamBase}}} - \frac{\text{EFOOD}_{\text{SteamGas}}}{\text{GasEFF}_{\text{SteamEE}}} \right) \times \%_{\text{Steam}}\]

\[\Delta \text{IdleEnergy}_{\text{ConvGas}} = \text{Change in total daily idle energy consumed by gas oven in convection mode} = \left[ \text{GasIDLE}_{\text{ConvBase}} \times \left( \text{HOURS} - \text{LB}_{\text{Gas}}/\text{GasPC}_{\text{ConvBase}} \times \%_{\text{Conv}} \right) \right] - \left[ \text{GasIDLE}_{\text{ConvEE}} \times \left( \text{HOURS} - \text{LB}_{\text{Gas}}/\text{GasPC}_{\text{ConvEE}} \times \%_{\text{Conv}} \right) \right]\]

\[\Delta \text{IdleEnergy}_{\text{SteamGas}} = \text{Change in total daily idle energy consumed by gas oven in convection mode} = \left[ \text{GasIDLE}_{\text{SteamBase}} \times \left( \text{HOURS} - \text{LB}_{\text{Gas}}/\text{GasPC}_{\text{SteamBase}} \times \%_{\text{Steam}} \right) \right] - \left[ \text{GasIDLE}_{\text{SteamEE}} \times \left( \text{HOURS} - \text{LB}_{\text{Gas}}/\text{GasPC}_{\text{SteamEE}} \times \%_{\text{Steam}} \right) \right]\]

Where:

\[\text{LB}_{\text{Gas}} = \text{Estimated mass of food cooked per day for gas oven (lbs/day)} = \text{Custom, or if unknown, use 200 lbs (if P < 15), 250 lbs (if 15 <= P 30), or 400 lbs (if P = >30)}\]

\[\text{EFOOD}_{\text{ConvGas}} = \text{Energy absorbed by food product for gas oven in convection mode} = \text{Custom or if unknown, use 250 Btu/lb}\]

\[\text{GasEFF} = \text{Cooking energy efficiency of gas oven} = \text{Custom or if unknown, use values from table below}\]

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>EE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GasEFF_{Conv}</td>
<td>52%</td>
<td>56%</td>
</tr>
<tr>
<td>GasEFF_{Steam}</td>
<td>39%</td>
<td>41%</td>
</tr>
</tbody>
</table>

\[\text{EFOOD}_{\text{SteamGas}} = \text{Energy absorbed by food product for gas oven in steam mode} = \text{Custom or if unknown, use 105 Btu/lb}\]

\[\text{GasIDLE}_{\text{base}} = \text{Idle energy rate (Btu/hr) of baseline gas oven} = \text{Custom or if unknown, use values from table below}\]

---

24 Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator  
### Pan Capacity

<table>
<thead>
<tr>
<th></th>
<th>Convection Mode (GasIDLE_ConvBase)</th>
<th>Steam Mode (GasIDLE_SteamBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>8,747</td>
<td>18,656</td>
</tr>
<tr>
<td>15-30</td>
<td>10,788</td>
<td>24,562</td>
</tr>
<tr>
<td>&gt;30</td>
<td>13,000</td>
<td>43,300</td>
</tr>
</tbody>
</table>

\[GasPC\_\text{Base} = \text{Production capacity (lbs/hr) of baseline gas oven}\]

\[= \text{Custom of if unknown, use values from table below}\]

### Pan Capacity

<table>
<thead>
<tr>
<th></th>
<th>Convection Mode (GasPC_ConvBase)</th>
<th>Steam Mode (GasPC_SteamBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>125</td>
<td>195</td>
</tr>
<tr>
<td>15-30</td>
<td>176</td>
<td>211</td>
</tr>
<tr>
<td>&gt;30</td>
<td>392</td>
<td>579</td>
</tr>
</tbody>
</table>

\[GasIDLE\_\text{ConvEE} = \text{Idle energy rate of ENERGY STAR gas oven in convection mode}\]

\[= 150\*P + 5,425\]

\[GasPC\_\text{EE} = \text{Production capacity (lbs/hr) of ENERGY STAR gas oven}\]

\[= \text{Custom of if unknown, use values from table below}\]

### Pan Capacity

<table>
<thead>
<tr>
<th></th>
<th>Convection Mode (GasPC_ConvEE)</th>
<th>Steam Mode (GasPC_SteamEE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 15</td>
<td>124</td>
<td>172</td>
</tr>
<tr>
<td>15-30</td>
<td>210</td>
<td>277</td>
</tr>
<tr>
<td>&gt;30</td>
<td>394</td>
<td>640</td>
</tr>
</tbody>
</table>

\[GasIDLE\_\text{SteamEE} = \text{Idle energy rate of ENERGY STAR gas oven in steam mode}\]

\[= 200 \* P +6511\]

\[100,000 = \text{Conversion factor from Btu to therms}\]

All other variables as defined above.
EXAMPLE

For example, a 10-pan capacity gas combination oven would save:

\[
\Delta \text{Therms} = (\Delta \text{CookingEnergy}_{\text{ConvGas}} + \Delta \text{CookingEnergy}_{\text{SteamGas}} + \Delta \text{IdleEnergy}_{\text{ConvGas}} + \\
\Delta \text{IdleEnergy}_{\text{SteamGas}}) \times \text{Days} / 100,000
\]

\[
\Delta \text{CookingEnergy}_{\text{ConvGas}} = 200 \times (250 / 0.52 - 250 / 0.56) \times 0.50
= 3,434 \text{ therms}
\]

\[
\Delta \text{CookingEnergy}_{\text{SteamGas}} = 200 \times (105 / 0.39 - 105 / 0.41) \times (1 - 0.50)
= 1,313 \text{ therms}
\]

\[
\Delta \text{IdleEnergy}_{\text{ConvGas}} = [(8,747 \times ((12 - 200/125) \times 0.50)) - (6,925 \times ((12 - 200/124) \times 0.50))]
= 9,519 \text{ therms}
\]

\[
\Delta \text{IdleEnergy}_{\text{SteamGas}} = [(18,658 \times ((12 - 200/195) \times (1 - 0.50))) - (8,511 \times ((12 - 200/172) \times (1 - 0.50)))]
= 56,251 \text{ therms}
\]

\[
\Delta \text{Therms} = (3,434 + 1,313 + 9,519 + 56,251) \times 365 /100,000
= 257 \text{ therms}
\]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-CBOV-V02-160601

REVIEW DEADLINE: 1/1/2023
4.2.2 Commercial Solid and Glass Door Refrigerators & Freezers

DESCRIPTION

This measure relates to the installation of a new reach-in commercial refrigerator or freezer meeting ENERGY STAR efficiency standards. ENERGY STAR labeled commercial refrigerators and freezers are more energy efficient because they are designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors, which will significantly reduce energy consumption.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a new vertical solid or glass door refrigerator or freezer or vertical chest freezer meeting the minimum ENERGY STAR efficiency level standards.

DEFINITION OF BASELINE EQUIPMENT

In order for this characterization to apply, the baseline equipment is assumed to be an existing solid or glass door refrigerator or freezer meeting the minimum federal manufacturing standards as specified by the Energy Policy Act of 2005.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Refrigerator Incremental Cost, per unit</th>
<th>Freezer Incremental Cost, per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid or Glass Door</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 &lt; V &lt; 15</td>
<td>$143</td>
<td>$142</td>
</tr>
<tr>
<td>15 ≤ V &lt; 30</td>
<td>$164</td>
<td>$166</td>
</tr>
<tr>
<td>30 ≤ V &lt; 50</td>
<td>$164</td>
<td>$166</td>
</tr>
<tr>
<td>V ≥ 50</td>
<td>$249</td>
<td>$407</td>
</tr>
</tbody>
</table>

LOADSHAPE

Loadshape C23 - Commercial Refrigeration

---


COINCIDENCE FACTOR
The summer peak coincidence factor for this measure is assumed to be 0.937.\(^{27}\)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = (\text{kWh}_{\text{base}} \ - \ \text{kWh}_{\text{eff}}) \times 365.25 \]

Where:

\( \text{kWh}_{\text{base}} = \) baseline maximum daily energy consumption in kWh

\( \text{kWh}_{\text{base}} = \) calculated using actual chilled or frozen compartment volume (\( V \)) of the efficient unit as shown in the table below.

<table>
<thead>
<tr>
<th>Type</th>
<th>kWh}_{\text{base}^{28}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Door Refrigerator</td>
<td>0.10 * V + 2.04</td>
</tr>
<tr>
<td>Glass Door Refrigerator</td>
<td>0.12 * V + 3.34</td>
</tr>
<tr>
<td>Solid Door Freezer</td>
<td>0.40 * V + 1.38</td>
</tr>
<tr>
<td>Glass Door Freezer</td>
<td>0.75 * V + 4.10</td>
</tr>
</tbody>
</table>

\( \text{kWh}_{\text{eff}}^{29} = \) efficient maximum daily energy consumption in kWh

\( \text{kWh}_{\text{eff}} = \) calculated using actual chilled or frozen compartment volume (\( V \)) of the efficient unit as shown in the table below.

<table>
<thead>
<tr>
<th>Type</th>
<th>Refrigerator kWh_{\text{eff}}</th>
<th>Freezer kWh_{\text{eff}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Door</td>
<td>( \leq 0.089V + 1.411 )</td>
<td>( \leq 0.250V + 1.250 )</td>
</tr>
<tr>
<td>Glass Door</td>
<td>( \leq 0.037V + 2.200 )</td>
<td>( \leq 0.400V \ - \ 1.000 )</td>
</tr>
<tr>
<td>Solid Door</td>
<td>( \leq 0.056V + 1.635 )</td>
<td>( \leq 0.163V + 6.125 )</td>
</tr>
<tr>
<td>Glass Door</td>
<td>( \leq 0.060V + 1.416 )</td>
<td>( \leq 0.158V + 6.333 )</td>
</tr>
<tr>
<td>Solid Door</td>
<td>( \leq 0.118V + 1.382 )</td>
<td>( \leq 0.607V + 0.893 )</td>
</tr>
<tr>
<td>Glass Door</td>
<td>( \leq 0.140V + 1.050 )</td>
<td>( \leq 0.733V \ - \ 1.000 )</td>
</tr>
<tr>
<td>Solid Door</td>
<td>( \leq 0.088V + 2.625 )</td>
<td>( \leq 0.250V + 13.500 )</td>
</tr>
<tr>
<td>Glass Door</td>
<td>( \leq 0.110V + 1.500 )</td>
<td>( \leq 0.450V + 3.500 )</td>
</tr>
</tbody>
</table>

\( V = \) the chilled or frozen compartment volume (\( \text{ft}^3 \)) (as defined in the Association of Home Appliance Manufacturers Standard HRF\( ^1 \)–1979)

\( V = \) Actual installed

\(^{27}\) The CF for Commercial Refrigeration was calculated based upon the Ameren provided eShapes


365.25 = days per year

For example a solid door refrigerator with a volume of 15 would save

\[ \Delta \text{kWh} = (3.54 - 2.76) \times 365.25 \]

\[ = 285 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta \text{kW} = \Delta \text{kWh} / \text{HOURS} \times \text{CF} \]

Where:

- **HOURS** = equipment is assumed to operate continuously, 24 hours per day, 365.25 days per year.
  
  \[ = 8766 \]

- **CF** = Summer Peak Coincidence Factor for measure
  
  \[ = 0.937 \]

For example a solid door refrigerator with a volume of 15 would save

\[ \Delta \text{kW} = \frac{285}{8766} \times 0.937 \]

\[ = 0.030 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-CSDO-V01-120601**

**REVIEW DEADLINE: 1/1/2019**
4.2.3 Commercial Steam Cooker

DESCRIPTION

To qualify for this measure the installed equipment must be an ENERGY STAR® steamer in place of a standard steamer in a commercial kitchen. Savings are presented dependent on the pan capacity and corresponding idle rate at heavy load cooking capacity and if the steamer is gas or electric.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be as follows:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR® qualified with 38% minimum cooking energy efficiency at heavy load (potato) cooking capacity for gas steam cookers.</td>
<td>ENERGY STAR® qualified with 50% minimum cooking energy efficiency at heavy load (potato) cooking capacity for electric steam cookers.</td>
</tr>
</tbody>
</table>

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is assumed to be a non-ENERGY STAR® commercial steamer at end of life. It is assumed that the efficient equipment and baseline equipment have the same number of pans.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years\(^\text{30}\).

DEEMED MEASURE COST

The incremental capital cost for this measure is $998\(^\text{31}\) for a natural gas steam cooker or $2490\(^\text{32}\) for an electric steam cooker.

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type\(^\text{33}\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
</tbody>
</table>

\(^{30}\)California DEER 2008 which is also used by both the Food Service Technology Center and ENERGY STAR®.

\(^{31}\)Source for incremental cost for efficient natural gas steamer is RSG Commercial Gas Steamer Workpaper, January 2012.

\(^{32}\)Source for efficient electric steamer incremental cost is $2,490 per 2009 PG&E Workpaper - PGECOFST104.1 - Commercial Steam Cooker - Electric and Gas as reference by KEMA in the ComEd C & I TRM.

Calculation of Savings

Formulas below are applicable to both gas and electric steam cookers. Please use appropriate lookup values and identified flags.

Energy Savings

\[
\Delta \text{Savings} = (\Delta \text{Idle Energy} + \Delta \text{Preheat Energy} + \Delta \text{Cooking Energy}) \times Z
\]

For a gas cooker:

\[
\Delta \text{Savings} = \Delta \text{Btu} \times \frac{1}{100,000} \times Z
\]

For an electric steam cooker:

\[
\Delta \text{Savings} = \Delta \text{kWh} \times Z
\]

Where:

\[Z = \text{days/yr steamer operating (use 365.25 days/yr if heavy use restaurant and exact number unknown)}\]

\[\Delta \text{Idle Energy} = (((1 - \text{CSM}\%_{\text{Baseline}}) \times \text{IDLE}_{\text{BASE}} + \text{CSM}\%_{\text{Baseline}} \times \text{PC}_{\text{BASE}} \times \text{EF}_{\text{FOOD}} / \text{EF}_{\text{BASE}}) \times (\text{HOURS}_{\text{day}} \times (F / \text{PC}_{\text{BASE}}) - (\text{PRE}_{\text{number}} \times 0.25))) - (((1 - \text{CSM}\%_{\text{ENERGYSTAR}}) \times \text{IDLE}_{\text{ENERGYSTAR}} + \text{CSM}\%_{\text{ENERGYSTAR}} \times \text{PC}_{\text{ENERGY}} \times \text{EF}_{\text{FOOD}} / \text{EF}_{\text{ENERGYSTAR}}) \times (\text{HOURS}_{\text{day}} \times (F / \text{PC}_{\text{ENERGY}}) - (\text{PRE}_{\text{number}} \times 0.25 ))))
\]

Where:

\[\text{CSM}\%_{\text{Baseline}} = \text{Baseline Steamer Time in Manual Steam Mode (% of time)} = 90\%^{34}\]

\[\text{IDLE}_{\text{Base}} = \text{Idle Energy Rate of Base Steamer}^{35}\]

<table>
<thead>
<tr>
<th>Number of Pans</th>
<th>IDLE - Gas, Btu/hr</th>
<th>IDLE - Electric, kw</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>11,000</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>14,667</td>
<td>1.33</td>
</tr>
<tr>
<td>5</td>
<td>18,333</td>
<td>1.67</td>
</tr>
<tr>
<td>6</td>
<td>22,000</td>
<td>2.0</td>
</tr>
</tbody>
</table>

\[\text{PC}_{\text{Base}} = \text{Production Capacity of Base Steamer}^{36}\]

<table>
<thead>
<tr>
<th>Number of Pans</th>
<th>PC_{\text{Base}}, gas (lbs/hr)</th>
<th>PC_{\text{base}}, electric (lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>65</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>87</td>
<td>93</td>
</tr>
</tbody>
</table>

---

34Food Service Technology Center 2011 Savings Calculator
35Food Service Technology Center 2011 Savings Calculator
36Production capacity per Food Service Technology Center 2011 Savings Calculator of 23.3333 lb/hr per pan for electric baseline steam cookers and 21.6667 lb/hr per pan for natural gas baseline steam cookers. ENERGY STAR® savings calculator uses 23.3 lb/hr per pan for both electric and natural gas baseline steamers.
<table>
<thead>
<tr>
<th>Number of Pans</th>
<th>PC_{BASE}, gas (lbs/hr)</th>
<th>PC_{BASE}, electric (lbs/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>108</td>
<td>117</td>
</tr>
<tr>
<td>6</td>
<td>130</td>
<td>140</td>
</tr>
</tbody>
</table>

$E_{FOOD}$ = Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food (Btu/lb or kW/lb)

$=105 \text{Btu/lb}$\text{\textsuperscript{37}} (gas steamers) or $0.0308$\text{\textsuperscript{8}} (electric steamers)

$EFF_{BASE}$ = Heavy Load Cooking Efficiency for Base Steamer

$=15\%$\text{\textsuperscript{39}} (gas steamers) or $26\%$\text{\textsuperscript{9}} (electric steamers)

$HOURS_{day}$ = Average Daily Operation (hours)

<table>
<thead>
<tr>
<th>Type of Food Service</th>
<th>Hours/day$^{39}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food, limited menu</td>
<td>4</td>
</tr>
<tr>
<td>Fast Food, expanded menu</td>
<td>5</td>
</tr>
<tr>
<td>Pizza</td>
<td>8</td>
</tr>
<tr>
<td>Full Service, limited menu</td>
<td>8</td>
</tr>
<tr>
<td>Full Service, expanded menu</td>
<td>7</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>6</td>
</tr>
<tr>
<td>Unknown</td>
<td>6$^{40}$</td>
</tr>
<tr>
<td>Custom</td>
<td>Varies</td>
</tr>
</tbody>
</table>

$F$ = Food cooked per day (lbs/day)

$=\text{custom or if unknown, use 100 lbs/day}$\text{\textsuperscript{41}}

$CSM_{ENERGYSTAR}$ = ENERGY STAR Steamer’s Time in Manual Steam Mode (% of time)$^{42}$

$=0\%$

$IDLE_{ENERGYSTAR}$ = Idle Energy Rate of ENERGY STAR$^{8}$\text{\textsuperscript{43}}

<table>
<thead>
<tr>
<th>Number of Pans</th>
<th>IDLE_{ENERGYSTAR} ~ gas, (Btu/hr)</th>
<th>IDLE_{ENERGYSTAR} ~ electric, (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6250</td>
<td>0.40</td>
</tr>
<tr>
<td>4</td>
<td>8333</td>
<td>0.53</td>
</tr>
<tr>
<td>5</td>
<td>10417</td>
<td>0.67</td>
</tr>
</tbody>
</table>

\textsuperscript{37}Reference ENERGY STAR$^{8}$ savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC.

\textsuperscript{38}Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies.


\textsuperscript{40}Unknown is average of other locations

\textsuperscript{41}Reference amount used by both Food Service Technology Center and ENERGY STAR$^{8}$ savings calculator

\textsuperscript{42}Reference information from the Food Service Technology Center siting that ENERGY STAR$^{8}$ steamers are not typically operated in constant steam mode, but rather are used in timed mode. Reference ENERGY STAR$^{8}$ savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC for efficient steamer. Both baseline & efficient steamer mode values should be considered for users in Illinois market.

\textsuperscript{43}Food Service Technology Center 2011 Savings Calculator
<table>
<thead>
<tr>
<th>Number of Pans</th>
<th>IDLE_{\text{ENERGY STAR}} - \text{gas}, (Btu/hr)</th>
<th>IDLE_{\text{ENERGY STAR}} - \text{electric}, (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>12500</td>
<td>0.80</td>
</tr>
</tbody>
</table>

\[ P_{\text{ENERGY}} = \text{Production Capacity of } \text{ENERGY STAR® Steamer} \]

<table>
<thead>
<tr>
<th>Number of Pans</th>
<th>P_{\text{ENERGY}} - \text{gas(lbs/hr)}</th>
<th>P_{\text{ENERGY}} - \text{electric (lbs/hr)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>73</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>92</td>
<td>83</td>
</tr>
<tr>
<td>6</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>

\[ \text{EFF}_{\text{ENERGYSTAR}} = \text{Heavy Load Cooking Efficiency for } \text{ENERGY STAR® Steamer} \]

\[ \text{EFF}_{\text{ENERGYSTAR}} = 38\%^{45} \text{ (gas steamer) or 50}\%^{15} \text{ (electric steamer)} \]

\[ \text{PRE}_{\text{number}} = \text{Number of preheats per day} \]

\[ \text{PRE}_{\text{number}} = 1^{46} \text{ (if unknown, use 1)} \]

\[ \Delta_{\text{Preheat Energy}} = (\text{PRE}_{\text{number}} \times \Delta_{\text{Preheat}}) \]

\[ \Delta_{\text{Cooking Energy}} = ((1/ \text{EFF}_{\text{BASE}}) - (1/ \text{EFF}_{\text{ENERGY STAR®}})) \times F \times E_{\text{FOOD}} \]

Where:

\[ \text{PRE}_{\text{number}} = \text{Number of Preheats per Day} \]

\[ \text{PRE}_{\text{number}} = 1^{47} \text{ (if unknown, use 1)} \]

\[ \text{PRE}_{\text{heat}} = \text{Preheat energy savings per preheat} \]

\[ \text{PRE}_{\text{heat}} = 11,000 \text{ Btu/preheat}^{48} \text{ (gas steamer) or 0.5 kWh/preheat}^{49} \text{ (electric steamer)} \]

\[ \Delta_{\text{Cooking Energy}} = ((1/ \text{EFF}_{\text{BASE}}) - (1/ \text{EFF}_{\text{ENERGY STAR®}})) \times F \times E_{\text{FOOD}} \]

Where:

\[ \text{EFF}_{\text{BASE}} = \text{Heavy Load Cooking Efficiency for Base Steamer} \]

\[ \text{EFF}_{\text{BASE}} = 15\%^{50} \text{ (gas steamer) or 26}\%^{28} \text{ (electric steamer)} \]

---

44Production capacity per Food Service Technology Center 2011 Savings Calculator of 18.3333 lb/hr per pan for gas ENERGY STAR® steam cookers and 16.6667 lb/hr per pan for electric ENERGY STAR® steam cookers. ENERGY STAR® savings calculator uses 16.7 lb/hr per pan for electric and 20 lb/hr for natural gas ENERGY STAR® steamers.

45Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for Tier 1A and Tier 1B qualified electric and natural gas steamer heavy cooking load energy efficiencies and http://www.energystar.gov/ia/partners/product_specs/program_reqs/Commercial_Steam_Cookers_Program_Requirements.pdf?7010-36eb

46Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC and Food

47Reference ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC and Food

48Ohio TRM which references 2002 Food Service Technology Center “Commercial Cooking Appliance Technology Assessment” Chapter 8: Steamers. This is time also used by ENERGY STAR® savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC. 11,000 Btu/preheat is from 72,000 Btu/hr * 15 min/hr / 60 min/hr for gas steamers and 0.5 kWh/preheat is from 6 kW/preheat * 15 min/hr / 60 min/hr

49Reference Food Service Technology Center 2011 Savings Calculator values for Baseline Preheat Energy.

50Reference Food Service Technology Center 2011 Savings Calculator values as used by Consortium for Energy Efficiency, Inc. for baseline electric and natural gas steamer heavy cooking load energy efficiencies.
EFF\textsubscript{ENERGYSTAR} = Heavy Load Cooking Efficiency for ENERGY STAR\textsuperscript{*} Steamer
= 38\%\textsuperscript{51} (gas steamer) or 50\%\textsuperscript{23} (electric steamer)

\( F \) = Food cooked per day (lbs/day)
= custom or if unknown, use 100 lbs/day\textsuperscript{52}

\( E_{\text{FOOD}} \) = Amount of Energy Absorbed by the food during cooking known as ASTM Energy to Food\textsuperscript{53}

\[
\begin{array}{|c|c|}
\hline
E_{\text{FOOD}} & \text{gas (Btu/lb)} & E_{\text{FOOD}} & \text{kWh/lb} \\
\hline
105\textsuperscript{54} & 0.0308\textsuperscript{55} \\
\hline
\end{array}
\]

\textbf{EXAMPLE}

For a gas steam cooker: A 3 pan steamer in a full service restaurant

\[
\Delta\text{Savings} = (\Delta\text{Idle Energy} + \Delta\text{Preheat Energy} + \Delta\text{Cooking Energy}) \times Z \times 1/100,000
\]
\[
\Delta\text{Idle Energy} = (((1.0) - 0.9) \times 11000 + 0.9 \times 65 \times 105 / 0.15) \times (7 - (100 / 65) - (1 * 0.25))) - (((1.0) \times 6250 + 0 \times 55 \times 105 / 0.38) \times (7 - (100 / 55) - (1 * 0.25)))
\]
\[
= 188,321
\]
\[
\Delta\text{Preheat Energy} = (1 \times 11,000)
\]
\[
= 11,000
\]
\[
\Delta\text{Cooking Energy} = (((1/ 0.15) - (1/ 0.38)) \times (100 \text{ lb/day} \times 105 \text{ btu/lb}))
\]
\[
= 42368
\]
\[
\Delta\text{Therms} = (188321 + 11000 + 42368) \times 365.25 \times 1/100,000
\]
\[
= 883 \text{ therms}
\]

For an electric steam cooker: A 3 pan steamer in a cafeteria:

\[
\Delta\text{Savings} = (\Delta\text{Idle Energy} + \Delta\text{Preheat Energy} + \Delta\text{Cooking Energy}) \times Z
\]
\[
\Delta\text{Idle Energy} = (((1- .9) \times 1.0 + .9 \times 70 \times 0.0308 / 0.26) \times (6 - (100 / 70) - (1 * 0.25))) - (((1.0) \times 0.4 + 0 \times 50 \times 0.0308 / 0.50) \times (6 - (100 / 50) - (1 * 0.25)))
\]
\[
= 31.18
\]
\[
\Delta\text{Preheat Energy} = (1 \times 0.5)
\]
\[
= 0.5
\]
\[
\Delta\text{Cooking Energy} = (((1/ 0.26) - (1/ 0.5)) \times (100 \times 0.0308)))
\]
\[
= 5.69
\]
\[
\Delta\text{kWh} = (31.18 + 0.5 + 5.69) \times 365.25 \text{ days}
\]

\textsuperscript{51} Ibid.
\textsuperscript{52} Amount used by both Food Service Technology Center and ENERGY STAR\textsuperscript{*} savings calculator
\textsuperscript{53} Reference ENERGY STAR\textsuperscript{*} savings calculator at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC.
\textsuperscript{54} Ibid.
\textsuperscript{55} Ibid.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

This is only applicable to the electric steam cooker.

\[ \Delta kW = \left( \frac{\Delta kWh}{(HOURS_{Day} * Days_{Year})} \right) \times CF \]

Where:

- \( CF \) = Summer Peak Coincidence Factor for measure is provided below for different locations\(^{56}\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
</tbody>
</table>

- \( Days_{Year} \) = Annual Days of Operation
- =custom or 365.25 days a year
- Other values as defined above

**EXAMPLE**

For 3 pan electric steam cooker located in a cafeteria:

\[ \Delta kW = \left( \frac{\Delta kWh}{(HOURS_{Day} * Days_{Year})} \right) \times CF \]

\[ = \left( \frac{13,649}{(6 * 365.25)} \right) \times 0.36 \]

\[ = 2.24 \text{ kW} \]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

This is applicable to both gas and electric steam cookers.

\[ \Delta Water = (W_{BASE} - W_{ENERGYSTAR}) \times HOURS_{Day} \times Days_{Year} \]

Where

- \( W_{BASE} \) = Water Consumption Rate of Base Steamer (gal/hr)
- \( = 40^{57} \)
- \( W_{ENERGYSTAR} \) = Water Consumption Rate of ENERGY STAR\(^{\text{®}}\) Steamer look up\(^{58}\)

<table>
<thead>
<tr>
<th>CEE Tier</th>
<th>gal/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 1A</td>
<td>15</td>
</tr>
<tr>
<td>Tier 1B</td>
<td>4</td>
</tr>
</tbody>
</table>


\(^{58}\)Source Consortium for Energy Efficiency, Inc. September 2010 "Program Design Guidance for Steamers" for Tier 1A and Tier 1B water requirements. Ohio Technical Reference Manual 2010 for 10 gal/hr water consumption which can be used when Tier level is not known.
## CEE Tier gal/hr

<table>
<thead>
<tr>
<th>CEE Tier</th>
<th>gal/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg Efficient</td>
<td>10</td>
</tr>
<tr>
<td>Avg Most Efficient</td>
<td>3</td>
</tr>
</tbody>
</table>

\[ \text{Days}_{\text{Year}} = \text{Annual Days of Operation} = \text{custom or 365.25 days a year}\]  

**EXAMPLE**

For example, an electric 3 pan steamer with average efficiency in a full service restaurant

\[ \Delta \text{Water} = (40 - 10) \times 7 \times 365.25 \]

\[ = 76,703 \text{ gallons} \]

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

**Measure Code: CI-FSE-STMC-V04-160601**

**Review Deadline: 1/1/2023**

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[59]Source for 365.25 days/yr is ENERGY STAR® savings calculator which references Food Service Technology research on average use, 2009.
4.2.4 Conveyor Oven

DESCRIPTION

This measure applies to natural gas fired high efficiency conveyor ovens installed in commercial kitchens replacing existing natural gas units with conveyor width greater than 25 inches.

Conveyor ovens are available using four different heating processes: infrared, natural convection with a ceramic baking hearth, forced convection or air impingement, or a combination of infrared and forced convection. Conveyor ovens are typically used for producing a limited number of products with similar cooking requirements at high production rates. They are highly flexible and can be used to bake or roast a wide variety of products including pizza, casseroles, meats, breads, and pastries.

Some manufacturers offer an air-curtain feature at either end of the cooking chamber that helps to keep the heated air inside the conveyor oven. The air curtain operates as a virtual oven wall and helps reduce both the idle energy of the oven and the resultant heat gain to the kitchen.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a natural gas conveyor oven with a tested baking energy efficiency > 42% and an idle energy consumption rate < 57,000 Btu/hr utilizing ASTM standard F1817.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an existing pizza deck oven at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 17 years.\(^{60}\)

DEEMED MEASURE COST

The incremental capital cost for this measure is $1800\(^{61}\).

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

Calculation of Savings

Electric Energy Savings

N/A

---


\(^{61}\) Ibid.
SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS
The annual natural gas energy savings from this measure is a deemed value equaling 884 Therms\(^2\).

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-FSE-CVOV-V02-180101

REVIEW DEADLINE: 1/1/2024

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\(^2\) The Resource Solutions Group Commercial Conveyor Oven – Gas workpaper from January 2012; Commercial Gas Conveyor Oven – Large Gas Savings (therms/unit).
4.2.5 ENERGY STAR Convection Oven

DESCRIPTION
This measure applies to natural gas fired ENERGY STAR convection ovens installed in a commercial kitchen.
This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be a natural gas convection oven with a cooking efficiency \( \geq 46\% \) utilizing ASTM standard 1496 and an idle energy consumption rate \(< 12,000 \text{ Btu/hr}\).\(^63\)

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is a natural gas convection oven that is not ENERGY STAR certified and is at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 12 years.\(^64\)

DEEMED MEASURE COST
The incremental capital cost for this measure is $50.\(^65\)

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS

\(^63\) Version 2.2. of the ENERGY STAR specification.

\(^64\) Lifetime from ENERGY STAR commercial griddle which cites reference as “FSTC research on available models, 2009” http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

\(^65\) Measure cost from ENERGY STAR which cites reference as “EPA research on available models using AutoQuotes, 2010” http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

\[ \Delta \text{Therms} = (\Delta \text{DailyIdle Energy} + \Delta \text{DailyPreheat Energy} + \Delta \text{DailyCooking Energy}) \times \text{Days} /100000 \]

Where:

\( \Delta \text{DailyIdleEnergy} = \text{IdleBase} \times \text{IdleBaseTime} - \text{IdleENERGYSTAR} \times \text{IdleENERGYSTARTime} \)

\( \Delta \text{DailyPreheatEnergy} = (\text{PreHeatNumberBase} \times \text{PreheatTimeBase} / 60 \times \text{PreheatRateBase}) - (\text{PreheatNumberENERGYSTAR} \times \text{PreheatTimeENERGYSTAR} / 60 \times \text{PreheatRateENERGYSTAR}) \)

\( \Delta \text{DailyCookingEnergy} = (\text{LB} \times \text{EFOOD} / \text{EffBase}) - (\text{LB} \times \text{EFOOD} / \text{EffENERGYSTAR}) \)

Where:

- \text{HOURSday} = \text{Average Daily Operation}
- \text{Days} = \text{Annual days of operation}
- \text{LB} = \text{Food cooked per day}
- \text{EffENERGYSTAR} = \text{Cooking Efficiency ENERGY STAR}
- \text{EffBase} = \text{Cooking Efficiency Baseline}
- \text{PCENERGYSTAR} = \text{Production Capacity ENERGY STAR}
- \text{PCBase} = \text{Production Capacity base}
- \text{PreheatNumberENERGYSTAR} = \text{Number of preheats per day}
- \text{PreheatNumberBase} = \text{Number of preheats per day}
- \text{PreheatTimeENERGYSTAR} = \text{preheat length}
- \text{PreheatTimeBase} = \text{preheat length}
- \text{PreheatRateENERGYSTAR} = \text{preheat energy rate high efficiency}
- \text{PreheatRateBase} = \text{preheat energy rate baseline}
- \text{IdleENERGYSTAR} = \text{Idle energy rate}
IdleBase  = Idle energy rate
          = custom or if unknown, use 18000 btu/h
IdleENERGYSTARTime  = ENERGY STAR Idle Time
                      = HOURsday-LB/PCENERGYSTAR – PreHeatTimeENERGYSTAR/60
                      = 12 – 100/80 – 15/60
                      = 10.5 hours
IdleBaseTime  = BASE Idle Time
              = HOURsday-LB/PCbase – PreHeatTimeBase/60
              = Custom or if unknown, use
              = 12 – 100/70-15/60
              = 10.3 hours
EFOOD  = ASTM energy to food
        = 250 btu/pound

EXAMPLE
For example, an ENERGY STAR Oven with a cooking energy efficiency of 46% and default values from above would save.

\[ \Delta \text{Therms} = (\Delta \text{Idle Energy} + \Delta \text{Preheat Energy} + \Delta \text{Cooking Energy}) \times \text{Days} / 100000 \]

Where:
\[ \Delta \text{DailyIdleEnergy} = (18000 \times 10.3) - (12000 \times 10.5) \]
\[ = 59,400 \text{ btu} \]
\[ \Delta \text{DailyPreheatEnergy} = (1 \times 15 / 60 \times 76000) - (1 \times 15 / 60 \times 44000) \]
\[ = 8,000 \text{ btu} \]
\[ \Delta \text{DailyCookingEnergy} = (100 \times 250 / .30) - (100 \times 250 / .46) \]
\[ = 28,986 \text{ btu} \]
\[ \Delta \text{Therms} = (59,400 + 8,000 + 28,986) \times 365.25 / 100000 \]
\[ = 352 \text{ therms} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-FSE-ESCV-V02-180101

REVIEW DEADLINE: 1/1/2024
4.2.6 ENERGY STAR Dishwasher

DESCRIPTION

This measure applies to ENERGY STAR high and low temp under counter, stationary single tank door type, single tank conveyor, and multiple tank conveyor dishwashers, as well as high temp pot, pan, and utensil dishwashers installed in a commercial kitchen.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR certified dishwasher meeting idle energy rate (kW) and water consumption (gallons/rack) limits, as determined by both machine type and sanitation approach (chemical/low temp versus high temp).

ENERGY STAR Requirements (Effective February 1, 2013)

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>High Temp Efficiency Requirements</th>
<th>Low Temp Efficiency Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Idle Energy Rate</td>
<td>Water Consumption</td>
</tr>
<tr>
<td>Under Counter</td>
<td>≤ 0.50 kW</td>
<td>≤ 0.86 GPR</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>≤ 0.70 kW</td>
<td>≤ 0.89 GPR</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>≤ 1.20 kW</td>
<td>≤ 0.58 GSF</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>≤ 1.50 kW</td>
<td>≤ 0.70 GPR</td>
</tr>
<tr>
<td>Multiple Tank Conveyor</td>
<td>≤ 2.25 kW</td>
<td>≤ 0.54 GPR</td>
</tr>
</tbody>
</table>

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a new dishwasher that is not ENERGY STAR certified.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be\(^{67}\)

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Equipment Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temp</td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>10</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>15</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>20</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>20</td>
</tr>
<tr>
<td>High Temp</td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>10</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>15</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>20</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>20</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>10</td>
</tr>
</tbody>
</table>

DEEMED MEASURE COST

The incremental capital cost for this measure is provided below\(^{68}\)

---

\(^{67}\) Lifetime from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “EPA/FSTC research on available models, 2013”

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

\(^{68}\) Measure cost from ENERGY STAR Commercial Kitchen Equipment Savings Calculator which cites reference as “EPA research on available models using AutoQuotes, 2012”
### Dishwasher Types and Incremental Cost

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Temp</strong></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>$50</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>$0</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>$0</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>$970</td>
</tr>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>$120</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>$770</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>$2,050</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>$970</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>$1,710</td>
</tr>
</tbody>
</table>

### LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

### COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different restaurant types:

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
</tbody>
</table>

### Algorithm

#### CALCULATION OF SAVINGS

ENERGY STAR dishwashers save energy in three categories: building water heating, booster water heating and idle energy. Building water heating and booster water heating could be either electric or natural gas.

#### ELECTRIC ENERGY SAVINGS

Custom calculation below, otherwise use deemed values found within the tables that follow.

\[
\Delta \text{kWh} = \Delta \text{Building Energy} + \Delta \text{Booster Energy} + \Delta \text{Idle Energy}
\]

Where:

\[
\Delta \text{Building Energy} = \text{Change in annual electric energy consumption of building water heater}
\]

\[
= [(\text{Water Use}_{\text{base}} \times \text{Racks Washed} \times \text{Days}) \times (\Delta T_{in} \times 1.0 \times 8.2 \div \text{Eff}_{\text{Heater}} \div 3,413)] - [(\text{Water Use}_{\text{ESTAR}} \times \text{Racks Washed} \times \text{Days}) \times (\Delta T_{in} \times 1.0 \times 8.2 \div \text{Eff}_{\text{Heater}} \div 3,413)]
\]

\[
\Delta \text{Booster Energy} = \text{Annual electric energy consumption of booster water heater}
\]

---


71 Booster water heater energy only applies to high-temperature dishwashers.
$$\Delta \text{IdleEnergy} = \text{Annual idle electric energy consumption of dishwasher}$$

$$\Delta \text{IdleEnergy} = [(\text{WaterUse}_{\text{Base}} \times \text{RacksWashed} \times \text{Days}) \times (\Delta T_{\text{in}} \times 1.0 \times 8.2 \div \text{Eff}_{\text{Heater}} \div 3,413)] - [(\text{WaterUse}_{\text{ESTAR}} \times \text{RacksWashed} \times \text{Days}) \times (\Delta T_{\text{in}} \times 1.0 \times 8.2 \div \text{Eff}_{\text{Heater}} \div 3,413)]$$

Where:

- \(\text{WaterUse}_{\text{Base}}\) = Water use per rack (gal) of baseline dishwasher
  
  = Custom or if unknown, use value from table below as determined by machine type and sanitation method

- \(\text{WaterUse}_{\text{ESTAR}}\) = Water use per rack (gal) of ENERGY STAR dishwasher
  
  = Custom or if unknown, use value from table below as determined by machine type and sanitation method

- \(\text{RacksWashed}\) = Number of racks washed per day
  
  = Custom or if unknown, use value from table below as determined by machine type and sanitation method

- \(\text{Days}\) = Annual days of dishwasher operation
  
  = Custom or if unknown, use 365.25 days per year

- \(\Delta T_{\text{in}}\) = Inlet water temperature increase (°F)
  
  = Custom or if unknown, use 70 °F for building water heaters and 40 °F for booster water heaters

- 1.0 = Specific heat of water (Btu/lb/°F)

- 8.2 = Density of water (lb/gal)

- \(\text{Eff}_{\text{Heater}}\) = Efficiency of water heater
  
  = Custom or if unknown, use 98% for electric building and booster water heaters

- 3,413 = kWh to Btu conversion factor

- \(\text{IdleDraw}_{\text{Base}}\) = Idle power draw (kW) of baseline dishwasher
  
  = Custom or if unknown, use value from table below as determined by machine type and sanitation method

- \(\text{IdleDraw}_{\text{ESTAR}}\) = Idle power draw (kW) of ENERGY STAR dishwasher
  
  = Custom or if unknown, use value from table below as determined by machine type and sanitation method

- \(\text{Hours}\) = Average daily hours of dishwasher operation
  
  = Custom or if unknown, use 18 hours per day

- \(\text{WashTime}\) = Typical wash time (min)
  
  = Custom or if unknown, use value from table below as determined by machine type and sanitation method

- 60 = Minutes to hours conversion factor
**EXAMPLE**

For example, an ENERGY STAR high-temperature, under counter dishwasher with electric building and electric booster water heating with defaults from the calculation above and the table below would save:

\[
\Delta \text{kWh} = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy} + \Delta \text{IdleEnergy}
\]

Where:

\[
\Delta \text{BuildingEnergy} = [(1.09 \times 75 \times 365.25) \times (70 \times 1.0 \times 8.2 \div 0.98 \div 3,413)] - [(0.86 \times 75 \times 365.25) \times (70 \times 1.0 \times 8.2 \div 0.98 \div 3,413)]
\]
\[
= 1,081 \text{ kWh}
\]

\[
\Delta \text{BoosterEnergy} = [(1.09 \times 75 \times 365.25) \times (40 \times 1.0 \times 8.2 \div 0.98 \div 3,413)] - [(0.86 \times 75 \times 365.25) \times (40 \times 1.0 \times 8.2 \div 0.98 \div 3,413)]
\]
\[
= 618 \text{ kWh}
\]

\[
\Delta \text{IdleEnergy} = [0.76 \times (18 \times 365.25 - 365.25 \times 75 \times 2.0 \div 60)] - [0.50 \times (18 \times 365.25 - 365.25 \times 75 \times 2.0 \div 60)]
\]
\[
= 1,472 \text{ Wh}
\]

\[
\Delta \text{kWh} = 1,081 + 618 + 1,472
\]
\[
= 3,171 \text{ kWh}
\]

Default values for WaterUse, RacksWashed, \(kW_{idle}\), and WashTime are presented in the table below.

<table>
<thead>
<tr>
<th>Low Temperature</th>
<th>RacksWashed</th>
<th>WashTime</th>
<th>WaterUse</th>
<th>IdleDraw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Dishwashers</td>
<td>All Dishwashers</td>
<td>Conventional</td>
<td>ENERGY STAR</td>
</tr>
<tr>
<td>Under Counter</td>
<td>75</td>
<td>2.0</td>
<td>1.73</td>
<td>1.19</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>280</td>
<td>1.5</td>
<td>2.10</td>
<td>1.18</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>400</td>
<td>0.3</td>
<td>1.31</td>
<td>0.79</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>600</td>
<td>0.3</td>
<td>1.04</td>
<td>0.54</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High Temperature</th>
<th>RacksWashed</th>
<th>WashTime</th>
<th>WaterUse</th>
<th>IdleDraw</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Dishwashers</td>
<td>All Dishwashers</td>
<td>Conventional</td>
<td>ENERGY STAR</td>
</tr>
<tr>
<td>Under Counter</td>
<td>75</td>
<td>2.0</td>
<td>1.09</td>
<td>0.86</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>280</td>
<td>1.0</td>
<td>1.29</td>
<td>0.89</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>400</td>
<td>0.3</td>
<td>0.87</td>
<td>0.70</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>600</td>
<td>0.2</td>
<td>0.97</td>
<td>0.54</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>280</td>
<td>3.0</td>
<td>0.70</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Savings for all water heating combinations are presented in the tables below (calculated without rounding variables as provided above).

**Electric building and electric booster water heating**

<table>
<thead>
<tr>
<th>Dishwasher type</th>
<th>kWh&lt;sub&gt;base&lt;/sub&gt;</th>
<th>kWh&lt;sub&gt;STAR&lt;/sub&gt;</th>
<th>ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>10,972</td>
<td>8,431</td>
<td>2,541</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>39,306</td>
<td>23,142</td>
<td>16,164</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>42,230</td>
<td>28,594</td>
<td>13,636</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>50,112</td>
<td>31,288</td>
<td>18,824</td>
</tr>
<tr>
<td>Under Counter</td>
<td>12,363</td>
<td>9,191</td>
<td>3,173</td>
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</table>
### ENERGY STAR Dishwasher

<table>
<thead>
<tr>
<th>Dishwasher type</th>
<th>kWh&lt;sub&gt;Base&lt;/sub&gt;</th>
<th>kWh&lt;sub&gt;ESTAR&lt;/sub&gt;</th>
<th>ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>39,852</td>
<td>27,981</td>
<td>11,871</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>45,593</td>
<td>36,375</td>
<td>9,218</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>72,523</td>
<td>45,096</td>
<td>27,426</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>21,079</td>
<td>17,766</td>
<td>3,313</td>
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<tr>
<td><strong>Electric building and natural gas booster water heating</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>10,972</td>
<td>8,431</td>
<td>2,541</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>39,306</td>
<td>23,142</td>
<td>16,164</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>42,230</td>
<td>28,594</td>
<td>13,636</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>50,112</td>
<td>31,288</td>
<td>18,824</td>
</tr>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>9,432</td>
<td>6,878</td>
<td>2,554</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>26,901</td>
<td>19,046</td>
<td>7,856</td>
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<td>Single Tank Conveyor</td>
<td>33,115</td>
<td>26,335</td>
<td>6,780</td>
</tr>
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<td>Multi Tank Conveyor</td>
<td>51,655</td>
<td>33,479</td>
<td>18,176</td>
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<td>Pot, Pan, and Utensil</td>
<td>14,052</td>
<td>11,943</td>
<td>2,108</td>
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<tr>
<td><strong>Natural gas building and electric booster water heating</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>2,831</td>
<td>2,831</td>
<td>0</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>2,411</td>
<td>2,411</td>
<td>0</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>9,350</td>
<td>8,766</td>
<td>584</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>10,958</td>
<td>10,958</td>
<td>0</td>
</tr>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>7,234</td>
<td>5,143</td>
<td>2,090</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>17,188</td>
<td>12,344</td>
<td>4,844</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>23,575</td>
<td>18,806</td>
<td>4,951</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>36,004</td>
<td>24,766</td>
<td>11,238</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>8,781</td>
<td>7,576</td>
<td>1,205</td>
</tr>
<tr>
<td><strong>Natural gas building and natural gas booster water heating</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>2,831</td>
<td>2,831</td>
<td>0</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>2,411</td>
<td>2,411</td>
<td>0</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>9,350</td>
<td>8,766</td>
<td>584</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>10,958</td>
<td>10,958</td>
<td>0</td>
</tr>
<tr>
<td><strong>High Temp</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>4,303</td>
<td>2,831</td>
<td>1,472</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>4,237</td>
<td>3,409</td>
<td>828</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>11,279</td>
<td>8,766</td>
<td>2,513</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>15,136</td>
<td>13,149</td>
<td>1,987</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>1,753</td>
<td>1,753</td>
<td>0</td>
</tr>
</tbody>
</table>

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \Delta kWh / \text{AnnualHours} \times CF
\]

Where:

\[
\text{AnnualHours} = \text{Hours} \times \text{Days}
\]
\[\text{CF} = \text{Summer Peak Coincidence Factor} = \text{dependent on restaurant type}^{72}\]

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Example:
A low temperature undercounter dishwasher in a Full Service Limited Menu restaurant with electric building and booster water heaters would save:

\[\Delta kW = \frac{\Delta kW/\text{Annual/Hours} \times \text{CF}}{0.197\text{ kW}}\]

\[\Delta kW = \frac{2541/6575 \times 0.51}{0.197}\]

\[\Delta kW = 0.197\text{ kW}\]

**Natural Gas Energy Savings**

\[\Delta \text{Therms}^{73} = \Delta \text{BuildingEnergy} + \Delta \text{BoosterEnergy}\]

Where:

\[\Delta \text{BuildingEnergy} = \text{Change in annual natural gas consumption of building water heater}\]

\[\Delta \text{BoosterEnergy} = \text{Change in annual natural gas consumption of booster water heater}\]

\[\begin{align*}
\Delta \text{BuildingEnergy} &= \left[\left(\text{WaterUse}_{\text{Base}} \times \text{RacksWashed} \times \text{Days}\right) \times (\Delta T_{\text{in}} \times 1.0 \times 8.2 \div \text{Eff}_{\text{Heater}} \div 100,000)\right] - \\
&\quad \left[\left(\text{WaterUse}_{\text{ESTAR}} \times \text{RacksWashed} \times \text{Days}\right) \times (\Delta T_{\text{in}} \times 1.0 \times 8.2 \div \text{Eff}_{\text{Heater}} \div 100,000)\right]
\end{align*}\]

Where:

\[\text{WaterUse}_{\text{Base}} = \text{Water use per rack (gal) of baseline dishwasher}\]

\[\text{WaterUse}_{\text{ESTAR}} = \text{Water use per rack (gal) of ENERGY STAR dishwasher}\]

\[\text{RacksWashed} = \text{Number of racks washed per day}\]

---


\(^{73}\) Algorithms and assumptions derived from ENERGY STAR Commercial Kitchen Equipment Savings Calculator
Savings for all water heating combinations are presented in the tables below.

**Electric building and natural gas booster water heating**

<table>
<thead>
<tr>
<th>Dishwasher type</th>
<th>Therm$S_{\text{Base}}$</th>
<th>Therm$S_{\text{ESTAR}}$</th>
<th>$\Delta$Therms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>High Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>123</td>
<td>97</td>
<td>26</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>541</td>
<td>374</td>
<td>168</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>522</td>
<td>420</td>
<td>102</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>872</td>
<td>486</td>
<td>387</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>294</td>
<td>243</td>
<td>50</td>
</tr>
</tbody>
</table>
Natural gas building and natural gas booster water heating

<table>
<thead>
<tr>
<th>Dishwasher type</th>
<th>ThermsBase</th>
<th>ThermsESTAR</th>
<th>ΔTherms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>340</td>
<td>234</td>
<td>106</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>1,543</td>
<td>867</td>
<td>676</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>1,375</td>
<td>829</td>
<td>546</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>1,637</td>
<td>850</td>
<td>787</td>
</tr>
<tr>
<td>High Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>337</td>
<td>266</td>
<td>71</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>1,489</td>
<td>1,027</td>
<td>462</td>
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<tr>
<td>Single Tank Conveyor</td>
<td>1,435</td>
<td>1,154</td>
<td>280</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>2,399</td>
<td>1,336</td>
<td>1,064</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>808</td>
<td>669</td>
<td>139</td>
</tr>
</tbody>
</table>

Natural gas building and electric booster water heating

<table>
<thead>
<tr>
<th>Dishwasher type</th>
<th>ThermsBase</th>
<th>ThermsESTAR</th>
<th>ΔTherms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>340</td>
<td>234</td>
<td>106</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>1,543</td>
<td>867</td>
<td>676</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>1,375</td>
<td>829</td>
<td>546</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>1,637</td>
<td>850</td>
<td>787</td>
</tr>
<tr>
<td>High Temp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>214</td>
<td>169</td>
<td>45</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>948</td>
<td>654</td>
<td>294</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>913</td>
<td>735</td>
<td>178</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>1,527</td>
<td>850</td>
<td>677</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>514</td>
<td>426</td>
<td>88</td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[
\Delta \text{Water} = (\text{WaterUse}_{\text{Base}} \times \text{RacksWashed} \times \text{Days}) - (\text{WaterUse}_{\text{ESTAR}} \times \text{RacksWashed} \times \text{Days})
\]

Where:

- \(\text{WaterUse}_{\text{Base}}\) = Water use per rack (gal) of baseline dishwasher
  
  = Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

- \(\text{WaterUse}_{\text{ESTAR}}\) = Water use per rack (gal) of ENERGY STAR dishwasher
  
  = Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

- \(\text{RacksWashed}\) = Number of racks washed per day
  
  = Custom or if unknown, use value from table within the electric energy savings characterization as determined by machine type and sanitation method

- \(\text{Days}\) = Annual days of dishwasher operation
  
  = Custom or if unknown, use 365 days per year
EXAMPLE

For example, an ENERGY STAR low-temperature, under counter dishwasher with defaults from the calculation above and the table within the electric energy savings characterization would save:

\[
\Delta \text{Water} = (\text{WaterUse}_{\text{Baseline}} \times \text{RacksWashed} \times \text{Days}) - (\text{WaterUse}_{\text{ENERGY STAR}} \times \text{RacksWashed} \times \text{Days})
\]

\[
\Delta \text{Water} = (1.73 \times 75 \times 365.25) - (1.19 \times 75 \times 365.25)
\]

\[
= 14,793 \text{ gallons}
\]

Savings for all dishwasher types are presented in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>ENERGY STAR</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low Temperature</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>47,391</td>
<td>32,599</td>
<td>14,793</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>214,767</td>
<td>120,679</td>
<td>94,088</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>191,391</td>
<td>115,419</td>
<td>75,972</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>227,916</td>
<td>118,341</td>
<td>109,575</td>
</tr>
<tr>
<td><strong>High Temperature</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under Counter</td>
<td>29,859</td>
<td>23,559</td>
<td>6,301</td>
</tr>
<tr>
<td>Stationary Single Tank Door</td>
<td>131,928</td>
<td>91,020</td>
<td>40,908</td>
</tr>
<tr>
<td>Single Tank Conveyor</td>
<td>127,107</td>
<td>102,270</td>
<td>24,837</td>
</tr>
<tr>
<td>Multi Tank Conveyor</td>
<td>212,576</td>
<td>118,341</td>
<td>94,235</td>
</tr>
<tr>
<td>Pot, Pan, and Utensil</td>
<td>71,589</td>
<td>59,317</td>
<td>12,272</td>
</tr>
</tbody>
</table>

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESDW-V03-180101**

**REVIEW DEADLINE: 1/1/2023**
4.2.7 ENERGY STAR Fryer

DESCRIPTION
This measure applies to natural gas fired ENERGY STAR fryer installed in a commercial kitchen.
This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be a natural gas fryer with a heavy load cooking efficiency ≥ 50% utilizing ASTM standard F1361 or F2144.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is a natural gas fryer that is not ENERGY STAR certified at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 15 years.\(^{74}\)

DEEMED MEASURE COST
The incremental capital cost for this measure is $1200.\(^{75}\)

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS\(^{76}\)
Custom calculation below, otherwise use deemed value of 505 Therms.

\[ \Delta \text{Therms} = (\Delta \text{DailyIdle Energy} + \Delta \text{DailyPreheat Energy} + \Delta \text{DailyCooking Energy}) \times \text{Days} / 100000 \]

\(^{74}\)Lifetime from ENERGY STAR commercial griddle which cites reference as “FSTC research on available models, 2009” http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

\(^{75}\)Measure cost from ENERGY STAR which cites reference as “EPA research on available models using AutoQuotes, 2010” http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG

Where:

\[ \Delta \text{DailyIdleEnergy} = (\text{IdleBase} \times \text{IdleBaseTime}) - (\text{IdleENERGYSTAR} \times \text{IdleENERGYSTARTime}) \]

\[ \Delta \text{DailyPreheatEnergy} = (\text{PreHeatNumberBase} \times \text{PreheatTimeBase} / 60 \times \text{PreheatRateBase}) - (\text{PreheatNumberENERGYSTAR} \times \text{PreheatTimeENERGYSTAR}/60 \times \text{PreheatRateENERGYSTAR}) \]

\[ \Delta \text{DailyCookingEnergy} = (\text{LB} \times \text{EFOOD} / \text{EffBase}) - (\text{LB} \times \text{EFOOD} / \text{EffENERGYSTAR}) \]

Where:

- \( \text{HOURSday} \) = Average Daily Operation
  - custom or if unknown, use 16 hours
- \( \text{Days} \) = Annual days of operation
  - custom or if unknown, use 365.25 days a year
- \( \text{LB} \) = Food cooked per day
  - custom or if unknown, use 150 pounds
- \( \text{EffENERGYSTAR} \) = Cooking Efficiency ENERGY STAR
  - custom or if unknown, use 50%
- \( \text{EffBase} \) = Cooking Efficiency Baseline
  - custom or if unknown, use 35%
- \( \text{PCENERGYSTAR} \) = Production Capacity ENERGY STAR
  - custom or if unknown, use 65 pounds/hr
- \( \text{PCBase} \) = Production Capacity base
  - custom or if unknown, use 60 pounds/hr
- \( \text{PreheatNumberENERGYSTAR} \) = Number of preheats per day
  - custom or if unknown, use 1
- \( \text{PreheatNumberBase} \) = Number of preheats per day
  - custom or if unknown, use 1
- \( \text{PreheatTimeENERGYSTAR} \) = preheat length
  - custom or if unknown, use 15 minutes
- \( \text{PreheatTimeBase} \) = preheat length
  - custom or if unknown, use 15 minutes
- \( \text{PreheatRateENERGYSTAR} \) = preheat energy rate high efficiency
  - custom or if unknown, use 62000 btu/h
- \( \text{PreheatRateBase} \) = preheat energy rate baseline
  - custom or if unknown, use 64000 btu/h
- \( \text{IdleENERGYSTAR} \) = Idle energy rate
  - custom or if unknown, use 9000 btu/h
- \( \text{IdleBase} \) = Idle energy rate
  - custom or if unknown, use 14000 btu/h
IdleENERGYSTARTime = ENERGY STAR Idle Time
= HOURsday-LB/PCENERGYSTAR – PreHeatTimeENERGYSTAR/60
= Custom or if unknown, use
= 16 – 150/65-15/60
= 13.44 hours

IdleBaseTime = BASE Idle Time
= HOURsday-LB/PCbase – PreHeatTimeBase/60
= Custom or if unknown, use
= 16 – 150/60-15/60
= 13.25 hours

EFOOD = ASTM energy to food
= 570 btu/pound

**EXAMPLE**

For example, an ENERGY STAR fryer with a tested heavy load cooking energy efficiency of 50% and an idle energy rate of 120,981 btu and an Idle Energy Consumption Rate 9000 btu would save.

\[ \Delta \text{Therms} = (\Delta \text{Idle Energy} + \Delta \text{Preheat Energy} + \Delta \text{Cooking Energy}) \times \text{Days} / 100000 \]

Where:

\[ \Delta \text{DailyIdleEnergy} = (18550 \times 13.25) - (120981 \times 13.44) \]
\[ = 64519 \text{ btu} \]

\[ \Delta \text{DailyPreheatEnergy} = (1 \times 15 / 60 \times 64000) - (1 \times 15 / 60 \times 62000) \]
\[ = 500 \text{ btu} \]

\[ \Delta \text{DailyCookingEnergy} = (150 \times 570 / .35) - (150 \times 570 / .5) \]
\[ = 73286 \text{ btu} \]

\[ \Delta \text{Therms} = (64519+500+73286) \times 365.25 / 100000 \]
\[ = 508 \text{ therms} \]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESFR-V01-120601**

**REVIEW DEADLINE: 1/1/2019**
4.2.8 ENERGY STAR Griddle

DESCRIPTION
This measure applies to electric and natural gas fired high efficiency griddle installed in a commercial kitchen.

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

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be an ENERGY STAR natural gas or electric griddle with a tested heavy load cooking energy efficiency of 70 percent (electric) 38 percent (gas) or greater and an idle energy rate of 2,650 Btu/hr per square foot of cooking surface or less, utilizing ASTM F1275. The griddle must have an Idle Energy Consumption Rate < 2,600 Btu/hr per square foot of cooking surface.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is an existing natural gas or electric griddle that’s not ENERGY STAR certified and is at end of use.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 12 years

DEEMED MEASURE COST
The incremental capital cost for this measure is $0 for an electric griddle and $60 for a gas griddle.

LOADSHAPE
Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR
Summer Peak Coincidence Factor for measure is provided below for different building type:

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
</tbody>
</table>

---

77 Lifetime from ENERGY STAR commercial griddle which cites reference as “FSTC research on available models, 2009”
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG
78 Measure cost from ENERGY STAR which cites reference as “EPA research on available models using AutoQuotes, 2010”
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COG
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh = (\Delta\text{Idle Energy} + \Delta\text{Preheat Energy} + \Delta\text{Cooking Energy}) \times \text{Days} /1000 \]

Where:

\[ \Delta\text{DailyIdleEnergy} = ([\text{IdleBase} \times \text{Width} \times \text{Depth} \times (\text{HOURSday} - (\text{LB} / (\text{PCBase} \times \text{Width} \times \text{Depth}))) - (\text{PreheatNumberBase} \times \text{PreheatTimeBase} / 60)] - ([\text{IdleENERGYSTAR} \times \text{Width} \times \text{Depth} \times (\text{HOURSday} - (\text{LB} / (\text{PCENERGYSTAR} \times \text{Width} \times \text{Depth}))) - (\text{PreheatNumberENERGYSTAR} \times \text{PreheatTimeENERGYSTAR} / 60] \]

\[ \Delta\text{DailyPreheatEnergy} = (\text{PreHeatNumberBase} \times \text{PreheatTimeBase} / 60 \times \text{PreheatRateBase} \times \text{Width} \times \text{Depth}) - (\text{PreheatNumberENERGYSTAR} \times \text{PreheatTimeENERGYSTAR} / 60 \times \text{PreheatRateENERGYSTAR} \times \text{Width} \times \text{Depth}) \]

\[ \Delta\text{DailyCookingEnergy} = (\text{LB} \times \text{EFOOD/ EffBase}) - (\text{LB} \times \text{EFOOD/ EffENERGYSTAR}) \]

Where:

- \text{HOURSday} = Average Daily Operation
  - = custom or if unknown, use 12 hours
- \text{Days} = Annual days of operation
  - = custom or if unknown, use 365.25 days a year
- \text{LB} = Food cooked per day
  - = custom or if unknown, use 100 pounds
- \text{Width} = Griddle Width
  - = custom or if unknown, use 3 feet
- \text{Depth} = Griddle Depth
  - = custom or if unknown, use 2 feet
- \text{EffENERGYSTAR} = Cooking Efficiency ENERGY STAR
  - = custom or if unknown, use 70%
- \text{EffBase} = Cooking Efficiency Baseline
  - = custom or if unknown, use 65%
- \text{PCENERGYSTAR} = Production Capacity ENERGY STAR
  - = custom or if unknown, use 40/6 = 6.67 pounds/hr/sq ft
- \text{PCBase} = Production Capacity base
  - = custom or if unknown, use 35/6 = 5.83 pounds/hr/sq ft
- \text{PreheatNumberENERGYSTAR} = Number of preheats per day
  - = custom or if unknown, use 1

---

PreheatNumberBase = Number of preheats per day
    = custom or if unknown, use 1

PreheatTimeENERGYSTAR = preheat length
    = custom or if unknown, use 15 minutes

PreheatTimeBase = preheat length
    = custom or if unknown, use 15 minutes

PreheatRateENERGYSTAR = preheat energy rate high efficiency
    = custom or if unknown, use 8000/6 = 1333 W/sq ft

PreheatRateBase = preheat energy rate baseline
    = custom or if unknown, use 16000/6 = 2667 W/sq ft

IdleENERGYSTAR = Idle energy rate
    = custom or if unknown, use 320 W/sq ft

IdleBase = Idle energy rate
    = custom or if unknown, use 400 W/sq ft

EFOOD = ASTM energy to food
    = 139 w/pound

For example, an ENERGY STAR griddle with a tested heavy load cooking energy efficiency of 70 percent or greater and an idle energy rate of 320 W per square foot of cooking surface or less would save.

\[
\Delta \text{Daily Idle Energy} = [400 \times 3 \times 2 \times (12 - \frac{100}{35/6} \times 3 \times 2)] - [320 \times 3 \times 2 \times (12 - \frac{100}{40/6} \times 3 \times 2)] - (1 \times 15/60) = 3583 \text{ W}
\]

\[
\Delta \text{Daily Preheat Energy} = (1 \times 15/60 \times 16000/6 \times 3 \times 2) - (1 \times 15/60 \times 8000/6 \times 3 \times 2) = 2000 \text{ W}
\]

\[
\Delta \text{Daily Cooking Energy} = (100 \times 139 / 0.65) - (100 \times 139 / 0.70) = 1527 \text{ W}
\]

\[
\Delta \text{kWh} = (2000+1527+3583) \times 365.25 /1000 = 2597 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
kW = \Delta \text{kWh/Hours} \times CF
\]

For example, an ENERGY STAR griddle in a cafeteria with a tested heavy load cooking energy efficiency of 70 percent or greater and an idle energy rate of 320 W per square foot of cooking surface or less would save

\[
= 2597 \text{ kWh/4308} \times 0.36
= 0.22 \text{ kW}
\]
**NATURAL GAS ENERGY SAVINGS**

Custom calculation below, otherwise use deemed value of 149 therms.

\[
\Delta \text{Therms} = (\Delta \text{Idle Energy} + \Delta \text{Preheat Energy} + \Delta \text{Cooking Energy}) \times \frac{\text{Days}}{100000}
\]

Where:

\[
\Delta \text{DailyIdleEnergy} = \left\{ \text{Idle Base} \times \text{Width} \times \text{Depth} \times (\text{HOURSday} - \left( \text{LB/} \left( \text{PC Base} \times \text{Width} \times \text{Depth} \right) \right)) - (\Delta \text{Preheat Number Base} \times \text{Preheat Time Base}/60) \right\} - \left\{ \text{Idle ENERGY STAR} \times \text{Width} \times \text{Depth} \times (\text{HOURSday} - \left( \text{LB/(PC ENERGY STAR} \times \text{Width} \times \text{Depth}) \right)) - \left( \Delta \text{Preheat Number ENERGY STAR} \times \text{Preheat Time ENERGY STAR}/60 \right) \right\}
\]

\[
\Delta \text{DailyPreheatEnergy} = (\text{Preheat Number Base} \times \text{Preheat Time Base}/60 \times \text{Preheat Rate Base} \times \text{Width} \times \text{Depth}) - (\Delta \text{Preheat Number ENERGY STAR} \times \text{Preheat Time ENERGY STAR}/60 \times \text{Preheat Rate ENERGY STAR} \times \text{Width} \times \text{Depth})
\]

\[
\Delta \text{DailyCookingEnergy} = (\text{LB} \times \text{EFOOD} / \text{Eff Base}) - (\text{LB} \times \text{EFOOD} / \text{Eff ENERGY STAR})
\]

Where (new variables only):

- **Eff ENERGY STAR** = Cooking Efficiency ENERGY STAR
  
  = custom or if unknown, use 38%

- **Eff Base** = Cooking Efficiency Baseline
  
  = custom or if unknown, use 32%

- **PC ENERGY STAR** = Production Capacity ENERGY STAR
  
  = custom or if unknown, use 45/6 = 7.5 pounds/hr/sq ft

- **PC Base** = Production Capacity baseline
  
  = custom or if unknown, use 25/6 = 4.17 pounds/hr/sq ft

- **Preheat Rate ENERGY STAR** = preheat energy rate high efficiency
  
  = custom or if unknown, use 60000/6 = 10000 btu/h/sq ft

- **Preheat Rate Base** = preheat energy rate baseline
  
  = custom or if unknown, use 84000/6 = 14000 btu/h/sq ft

- **Idle ENERGY STAR** = Idle energy rate
  
  = custom or if unknown, use 15900/6 = 2650 btu/h/sq ft

- **Idle Base** = Idle energy rate
  
  = custom or if unknown, use 21000/6 = 3500 btu/h/sq ft

- **EFOOD** = ASTM energy to food
  
  = 475 btu/pound
For example, an ENERGY STAR griddle with a tested heavy load cooking energy efficiency of 38 percent or greater and an idle energy rate of 2,650 Btu/h per square foot of cooking surface or less and an Idle Energy Consumption Rate < 2,600 Btu/h per square foot of cooking surface would save.

\[
\Delta \text{Daily Idle Energy} = \left[3500 \times 3 \times 2 \times (12 - \frac{100}{25/6 \times 3 \times 2}) - (1 \times \frac{15}{60})\right] - \left[(2650 \times 3 \times 2 \times (12 - \frac{100}{45/6 \times 3 \times 2}) - (1 \times \frac{15}{60}))\right]
\]

\[
= 11258 \text{ Btu}
\]

\[
\Delta \text{Daily Preheat Energy} = (1 \times \frac{15}{60} \times 14000 \times 3 \times 2) - (1 \times \frac{15}{60} \times 10000 \times 3 \times 2)
\]

\[
= 6000 \text{ btu}
\]

\[
\Delta \text{ Daily Cooking Energy} = (100 \times \frac{475}{0.32}) - (100 \times \frac{475}{0.38})
\]

\[
= 23438 \text{ btu}
\]

\[
\Delta \text{ Therms} = (11258 + 6000 + 23438) \times \frac{365.25}{100000}
\]

\[
= 149 \text{ therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESGR-V02-160601**

**REVIEW DEADLINE: 1/1/2023**
4.2.9 ENERGY STAR Hot Food Holding Cabinets

DESCRIPTION

This measure applies to electric ENERGY STAR hot food holding cabinets (HFHC) installed in a commercial kitchen. This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be an ENERGY STAR certified HFHC.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is an electric HFHC that's not ENERGY STAR certified and at end of life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years\(^81\)

DEEMED MEASURE COST

The incremental capital cost for this measure is\(^82\)

<table>
<thead>
<tr>
<th>HFHC Size</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Size (20 cubic feet)</td>
<td>$1200</td>
</tr>
<tr>
<td>¾ Size (12 cubic feet)</td>
<td>$1800</td>
</tr>
<tr>
<td>½ Size (8 cubic feet)</td>
<td>$1500</td>
</tr>
</tbody>
</table>

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type\(^83\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
</tbody>
</table>

\(^81\) Lifetime from ENERGY STAR HFHC which cites reference as “FSTC research on available models, 2009” http://www.energystar.gov/index.cfm?FuseAction=find_a_product.showProductGroup&pgw_code=COG
\(^82\) Measure cost from ENERGY STAR which cites reference as “EPA research on available models using AutoQuotes, 2010” http://www.energystar.gov/index.cfm?Fuseaction=find_a_product.showProductGroup&pgw_code=COG
Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Custom calculation below, otherwise use deemed values depending on HFHC size\(^{84}\)

<table>
<thead>
<tr>
<th>Cabinet Size</th>
<th>Savings (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Size HFHC</td>
<td>9308</td>
</tr>
<tr>
<td>¾ Size HFHC</td>
<td>3942</td>
</tr>
<tr>
<td>½ Size HFHC</td>
<td>2628</td>
</tr>
</tbody>
</table>

\[ \Delta kWh = \text{HFHCBaseline kWh} - \text{HFHCENERGYSTAR kWh} \]

Where:

\[ \text{HFHCBaseline kWh} = \text{PowerBaseline} \times \text{HOURS day} \times \text{Days/1000} \]

\[ \text{PowerBaseline} = \text{Custom}, \text{otherwise} \]

<table>
<thead>
<tr>
<th>Cabinet Size</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Size HFHC</td>
<td>2500</td>
</tr>
<tr>
<td>¾ Size HFHC</td>
<td>1200</td>
</tr>
<tr>
<td>½ Size HFHC</td>
<td>800</td>
</tr>
</tbody>
</table>

\[ \text{HOURS day} = \text{Average Daily Operation} \]

\[ = \text{custom or if unknown, use 15 hours} \]

\[ \text{Days} = \text{Annual days of operation} \]

\[ = \text{custom or if unknown, use 365.25 days a year} \]

\[ \text{HFHCENERGYSTAR kWh} = \text{PowerENERGYSTAR} \times \text{HOURS day} \times \text{Days/1000} \]

\[ \text{PowerENERGYSTAR} = \text{Custom}, \text{otherwise} \]

<table>
<thead>
<tr>
<th>Cabinet Size</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Size HFHC</td>
<td>800</td>
</tr>
<tr>
<td>¾ Size HFHC</td>
<td>480</td>
</tr>
<tr>
<td>½ Size HFHC</td>
<td>320</td>
</tr>
</tbody>
</table>

\[ \text{HOURS day} = \text{Average Daily Operation} \]

\[ = \text{custom or if unknown, use 15 hours} \]

\[ \text{Days} = \text{Annual days of operation} \]

\[ = \text{custom or if unknown, use 365.25 days a year} \]

---

For example, if a full size HFHC is installed the measure would save:
\[
\Delta \text{kWh} = \frac{(\text{PowerBaseline} \times \text{HOURSday} \times \text{Days})}{1000} - \frac{(\text{PowerENERGYSTAR} \times \text{HOURSday} \times \text{Days})}{1000}
\]
\[
= \frac{(2500 \times 15 \times 365.25)}{1000} - \frac{(800 \times 15 \times 365.25)}{1000}
\]
\[
= 9,314 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta \text{kW} = \frac{\Delta \text{kWh}}{\text{Hours}} \times \text{CF}
\]

\[
\text{Where: Hours} = \text{Hoursday} \times \text{Days}
\]

For example, if a full size HFHC is installed in a cafeteria the measure would save:
\[
= \frac{9,314 \text{ kWh}}{(15 \times 365.25) \times .36}
\]
\[
= 0.61 \text{ kW}
\]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-ESHH-V02-160601**

**REVIEW DEADLINE: 1/1/2023**
4.2.10 ENERGY STAR Ice Maker

DESCRIPTION
This measure relates to the installation of a new ENERGY STAR qualified commercial ice machine. The ENERGY STAR label applied to air-cooled, cube-type machines including ice-making head, self-contained, and remote-condensing units. This measure excludes flake and nugget type ice machines. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building.

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

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, the efficient equipment is assumed to be a new commercial ice machine meeting the minimum ENERGY STAR efficiency level standards.

DEFINITION OF BASELINE EQUIPMENT
In order for this characterization to apply, the baseline equipment is assumed to be a commercial ice machine meeting federal equipment standards established January 1, 2010.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 10 years.\(^\text{85}\)

DEEMED MEASURE COST
The incremental capital cost for this measure is provided below.\(^\text{86}\)

<table>
<thead>
<tr>
<th>Harvest Rate (H)</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-200 lb ice machine</td>
<td>$296</td>
</tr>
<tr>
<td>201-300 lb ice machine</td>
<td>$312</td>
</tr>
<tr>
<td>301-400 lb ice machine</td>
<td>$559</td>
</tr>
<tr>
<td>401-500 lb ice machine</td>
<td>$981</td>
</tr>
<tr>
<td>501-1000 lb ice machine</td>
<td>$1,485</td>
</tr>
<tr>
<td>1001-1500 lb ice machine</td>
<td>$1,821</td>
</tr>
<tr>
<td>&gt;1500 lb ice machine</td>
<td>$2,194</td>
</tr>
</tbody>
</table>

LOADSHAPE
Loadshape C23 - Commercial Refrigeration

COINCIDENCE FACTOR
The Summer Peak Coincidence Factor is assumed to equal 0.937

---

\(^{85}\text{DEER 2008}\)

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta k\text{WH} = \frac{(kWh_{\text{base}} - kWh_{\text{ee}})}{100} \times (DC \times H) \times 365.25 \]

Where:

- \( kWh_{\text{base}} \) = maximum kWh consumption per 100 pounds of ice for the baseline equipment
  - calculated as shown in the table below using the actual Harvest Rate (H) of the efficient equipment.
- \( kWh_{\text{ee}} \) = maximum kWh consumption per 100 pounds of ice for the efficient equipment
  - calculated as shown in the table below using the actual Harvest Rate (H) of the efficient equipment.

<table>
<thead>
<tr>
<th>Ice Machine Type</th>
<th>kWhbase(^{87})</th>
<th>kWhee(^{88})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice Making Head (H &lt; 450)</td>
<td>10.26 - 0.0086*H</td>
<td>9.23 - 0.0077*H</td>
</tr>
<tr>
<td>Ice Making Head (H ≥ 450)</td>
<td>6.89 - 0.0011*H</td>
<td>6.20 - 0.0010*H</td>
</tr>
<tr>
<td>Remote Condensing Unit, without remote compressor (H &lt; 1000)</td>
<td>8.85 - 0.0038*H</td>
<td>8.05 - 0.0035*H</td>
</tr>
<tr>
<td>Remote Condensing Unit, without remote compressor (H ≥ 1000)</td>
<td>5.1</td>
<td>4.64</td>
</tr>
<tr>
<td>Remote Condensing Unit, with remote compressor (H &lt; 934)</td>
<td>8.85 - 0.0038*H</td>
<td>8.05 - 0.0035*H</td>
</tr>
<tr>
<td>Remote Condensing Unit, with remote compressor (H ≥ 934)</td>
<td>5.3</td>
<td>4.82</td>
</tr>
<tr>
<td>Self Contained Unit (H &lt; 175)</td>
<td>18 - 0.0469*H</td>
<td>16.7 - 0.0436*H</td>
</tr>
<tr>
<td>Self Contained Unit (H ≥ 175)</td>
<td>9.8</td>
<td>9.11</td>
</tr>
</tbody>
</table>

100 = conversion factor to convert kWhbase and kWhee into maximum kWh consumption per pound of ice.

DC = Duty Cycle of the ice machine

\[ DC = 0.57^{89} \]

H = Harvest Rate (pounds of ice made per day)

= Actual installed

---

\(^{87}\)Baseline reflects federal standards which apply to units manufactured on or after January 1, 2010 <http://ecfr.gpoaccess.gov/cgi/t/text/text-id?c=ecfr&rgn=div6&view=text&node=10:3.0.1.4.17.8&idno=10>.


\(^{89}\)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/bsavings_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). The value of 57% was utilized since it appears to represent a high quality data source.
365.35 = days per year

For example an ice machine with an ice making head producing 450 pounds of ice would save

$\Delta kWh = \left(\frac{6.4 - 5.8}{100}\right) \times (0.57 \times 450) \times 365.25$

$= 562 \text{ kWh}$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$\Delta kW = \frac{\Delta kWh}{(\text{HOURS} \times \text{DC}) \times \text{CF}}$

Where:

- HOURS = annual operating hours
  - $= 8766^{90}$
- CF = 0.937

For example an ice machine with an ice making head producing 450 pounds of ice would save

$\Delta kW = \frac{562}{(8766 \times 0.57) \times 0.937}$

$= 0.105 \text{ kW}$

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

While the ENERGY STAR labeling criteria require that certified commercial ice machines meet certain “maximum potable water use per 100 pounds of ice made” requirements, such requirements are intended to prevent equipment manufacturers from gaining energy efficiency at the cost of water consumptions. A review of the AHRI Certification Directory\(^91\) indicates that approximately 81% of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement. Therefore, there are no assumed water impacts for this measure.

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** CI-FSE-ESIM-V01-120601

**REVIEW DEADLINE:** 1/1/2019

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\(^90\)Unit is assumed to be connected to power 24 hours per day, 365.25 days per year.

4.2.11 High Efficiency Pre-Rinse Spray Valve

DESCRIPTION
Pre-rise valves use a spray of water to remove food waste from dishes prior to cleaning in a dishwasher. More efficient spray valves use less water thereby reducing water consumption, water heating cost, and waste water (sewer) charges. Pre-rinse spray valves include a nozzle, squeeze lever, and dish guard bumper. The primary impacts of this measure are water savings. Reduced hot water consumption saves either natural gas or electricity, depending on the type of energy the hot water heater uses.

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

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure, the new or replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute with a cleanability performance of 26 seconds per plate or less.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment will vary based on the delivery method and is defined below:

<table>
<thead>
<tr>
<th>Time of Sale</th>
<th>Retrofit, Direct Install</th>
</tr>
</thead>
<tbody>
<tr>
<td>The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006.</td>
<td>The baseline equipment is assumed to be an existing pre-rinse spray valve with a flow rate of 1.9 gallons per minute. If existing pre-rinse spray valve flow rate is unknown, then existing pre-rinse spray valve must have been installed prior to 2006. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. However, field data shows that not all nozzles in use have been replaced with the newer flow rate nozzle. Products predating this standard can use up to five gallons per minute</td>
</tr>
</tbody>
</table>

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 5 years

DEEMED MEASURE COST
When available, the actual cost of the measure (including labor where applicable) should be used. If unknown, a default value of $92.90 may be assumed.

LOADSHAPE
Loadshape C01 - Commercial Electric Cooking

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92 Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively. from IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) (“CUWCC Report”, Feb 2007)


94Average of costs recognized by Ameren Missouri ($85.8) and KCPL ($100).
**COINCIDENCE FACTOR**

N/A

<table>
<thead>
<tr>
<th>Algorithm</th>
</tr>
</thead>
</table>

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS (NOTE WATER SAVINGS MUST FIRST BE CALCULATED)**

\[ \Delta kWH = \Delta \text{Gallons} \times 8.33 \times 1 \times (Tout - Tin) \times \left(\frac{1}{\text{EFF}_\text{Elec}}\right) / 3,413 \times \text{FLAG} \]

Where:

\[ \Delta \text{Gallons} \] = amount of water saved as calculated below  
\[ 8.33 \] = specific mass in pounds of one gallon of water (lbm/gal)  
\[ 1 \] = Specific heat of water: 1 Btu/lbm/°F  
\[ Tout \] = Water Heater Outlet Water Temperature  
\[ Tin \] = Inlet Water Temperature  
\[ \text{EFF}_\text{Elec} \] = Efficiency of electric water heater supplying hot water to pre-rinse spray valve  
\[ \text{Flag} \] = 1 if electric or 0 if gas

**EXAMPLE**

**Time of Sale:** For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by electric hot water saves annually:

\[ \Delta kWH = 30,326 \times 8.33 \times 1 \times ((70 + 54.1) - 54.1) \times \left(\frac{1}{0.97}\right) / 3,413 \times 1 \]

= 5,341 kWh

**Retrofit:** For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.9 gal/min flow at a large institutional establishments with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by electric hot water equals:

\[ \Delta kWH = 47,175 \times 8.33 \times 1 \times ((70 + 54.1) - 54.1) \times \left(\frac{1}{0.97}\right) / 3,413 \times 1 \]

= 8309 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

---

95If unknown, assume a 70 degree temperature rise from Tin per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies  
96August 31, 2011 Memo of Savings for Hot Water Savings Measures to Nicor Gas from Navigant states that 54.1°F was calculated from the weighted average of monthly water mains temperatures reported in the 2010 Building America Benchmark Study for Chicago-Waukegan, Illinois.  
97This efficiency value is based on IECC 2012/2015 performance requirement for electric resistant water heaters rounded without the slight adjustment allowing for reduction based on size of storage tank.
**Natural Gas Energy Savings**

\[
\Delta \text{Therms} = \Delta \text{Gallons} \times 8.33 \times 1 \times (\text{Tout} - \text{Tin}) \times \left(1/\text{EFF}_{\text{Gas}}\right) /100,000 \times (1 - \text{FLAG})
\]

Where (new variables only):

- **EFF\_Gas** = Efficiency of gas water heater supplying hot water to pre-rinse spray valve
  - custom, otherwise assume 80%

---

**Example**

**Time of Sale:** For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishment with a cafeteria with 70 degree temperature of water used by the pre-rinse spray valve that is heated by fossil fuel hot water saves annually:

\[
\Delta \text{Therms} = 30,326 \times 8.33 \times 1 \times ((70+54.1) - 54.1) \times (1/0.80) /100,000 \times (1-0)
\]

= 221 Therms

**Retrofit:** For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.9 gal/min flow at a busy large institutional establishment with a cafeteria with 70 degree temperature rise of water used by the pre-rinse spray valve that is heated by fossil fuel hot water saves annually:

\[
\Delta \text{Therms} = 47,175 \times 8.33 \times 1 \times ((70+54.1) - 54.1) \times (1/0.80) /100,000 \times (1-0)
\]

= 344 Therms

---

**Water Impact Calculation**

\[
\Delta \text{Gallons} = (\text{FLObase} - \text{FLOeff}) \times 60 \times \text{HOURSday} \times \text{DAYSyear}
\]

Where:

- **FLObase** = Base case flow in gallons per minute, or custom (Gal/min)
- **FLOeff** = Efficient case flow in gallons per minute or custom (Gal/min)

<table>
<thead>
<tr>
<th>Time of Sale</th>
<th>Retrofit, Direct Install</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6 gal/min(^{100})</td>
<td>1.9 gal/min(^ {101})</td>
</tr>
</tbody>
</table>

---

\(^{98}\) IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

\(^{99}\) In order to calculate energy savings, water savings must first be calculated

\(^{100}\) The baseline equipment is assumed to be 1.6 gallons per minute. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 gallons per minute at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. www1.eere.energy.gov/femp/pdfs/spec_prerinsesprayvavles.pdf.

\(^{101}\) Verification measurements taken at 195 installations showed average pre and post flow rates of 2.23 and 1.12 gallon per minute, respectively, from IMPACT AND PROCESS EVALUATION FINAL REPORT for CALIFORNIA URBAN WATER CONSERVATION COUNCIL 2004-5 PRE-RINSE SPRAY VALVE INSTALLATION PROGRAM (PHASE 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) ("CUWCC Report", Feb 2007).

\(^{102}\) 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

\(^{103}\) 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site
60 = Minutes per hour
HOURS/day = Hours per day that the pre-rinse spray valve is used at the site, custom, otherwise:

<table>
<thead>
<tr>
<th>Application</th>
<th>Hours/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small, quick-service restaurants</td>
<td>1</td>
</tr>
<tr>
<td>Medium-sized casual dining restaurants</td>
<td>1.5</td>
</tr>
<tr>
<td>Large institutional establishments with cafeteria</td>
<td>3</td>
</tr>
</tbody>
</table>

DAYS/year = Days per year pre-rinse spray valve is used at the site, custom, otherwise 312 days/yr based on assumed 6 days/wk x 52 wk/yr = 312 day/yr.

**EXAMPLE**

**Time of Sale:** For example, a new spray nozzle with 1.06 gal/min flow replacing a nozzle with 1.6 gal/min flow at a large institutional establishment with a cafeteria equals

\[(1.6 - 1.06) \times 60 \times 3 \times 312\]  
\[= 30,326 \text{ gal/yr}\]

**Retrofit:** For example, a new spray nozzle with 106 gal/min flow replacing a nozzle with 1.9 gal/min flow at a large institutional establishments with a cafeteria equals

\[(1.9 - 1.06) \times 60 \times 3 \times 312\]  
\[= 47,175 \text{ gal/yr}\]

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** CI-FSE-SPRY-V04-180101

**REVIEW DEADLINE:** 1/1/2023

with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

4.2.12 Infrared Charbroiler

**DESCRIPTION**
This measure applies to natural gas fired charbroilers that utilize infrared burners installed in a commercial kitchen. This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**
To qualify for this measure the installed equipment must be a new natural gas charbroiler with infrared burners.

**DEFINITION OF BASELINE EQUIPMENT**
The baseline equipment is an existing natural gas charbroiler without infrared burners.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The expected measure life is assumed to be 12 years.\(^{105}\)

**DEEMED MEASURE COST**
The incremental capital cost for this measure is $2173.\(^{106}\)

**LOADSHAPE**
N/A

**COINCIDENCE FACTOR**
N/A

**Calculation of Savings**

**Electric Energy Savings**
N/A

**Summer Coincident Peak Demand Savings**
N/A

**Natural Gas Energy Savings**
Custom calculation below, otherwise use deemed value of 707 therms based on default values.\(^{107}\)

\[
\Delta \text{Therms} = \left( \Delta \text{PreheatEnergy} + \Delta \text{CookingEnergy} \right) \times \text{Days} \over 100,000
\]

\[
\Delta \text{PreheatEnergy} = \left( \text{PreheatRate}_{\text{Base}} - \text{PreheatRate}_{\text{EE}} \right) \times \text{Preheats} \times \left( \frac{\text{PreheatTime}}{60} \right)
\]

---

\(^{105}\) Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.


\(^{107}\) Assumptions derived from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment, http://www.fishnick.com/equipment/techassessment/4_broilers.pdf
\[ \Delta \text{CookingEnergy} = (\text{InputRate}_{\text{Base}} - \text{InputRate}_{\text{EE}}) \times (\text{Duty} \times \text{Hours}) \]

Where:

- **Days** = Annual days of operation
- **100,000** = Btu to therms conversion factor
- **PreheatRate}_{\text{Base}}** = Preheat energy rate of baseline charbroiler
  - **64,000 Btu/hr**
- **PreheatRate}_{\text{EE}}** = Preheat energy rate of infrared charbroiler
  - **Custom or if unknown, use 54,000 Btu/hr**
- **Preheats** = Number of preheats per day
  - **Custom or if unknown, use 1 preheat per day**
- **PreheatTime** = Length of one preheat
  - **Custom or if unknown, use 15 minutes per preheat**
- **60** = Minutes to hours conversion factor
- **InputRate}_{\text{Base}}** = Input energy rate of baseline charbroiler
  - **140,000 Btu/hr**
- **InputRate}_{\text{EE}}** = Input energy rate of infrared charbroiler
  - **Custom or if unknown, use 105,000 Btu/hr**
- **Duty** = Duty cycle of charbroiler (%)
  - **Custom or if unknown, use 80%**
- **Hours** = Average daily hours of operation
  - **Custom or if unknown, use 8 hours per day**

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IRCB-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

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\(^{108}\)Typical annual operating time from FSTC Broiler Technology Assessment, Table 4.3

\(^{109}\)Typical preheat time from FSTC Broiler Technology Assessment.

\(^{110}\)Duty cycle from FSTC Broiler Technology Assessment, Table 4.3
4.2.13 Infrared Rotisserie Oven

DESCRIPTION
This measure applies to natural gas fired high efficiency rotisserie ovens utilizing infrared burners and installed in a commercial kitchen.
This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be a new natural gas rotisserie oven with infrared burners.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is an existing natural gas rotisserie oven without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 12 years.\(^{111}\)

DEEMED MEASURE COST
The incremental capital cost for this measure is $2665.\(^{112}\)

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS
Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 599 therms, based on default values.

\[
\Delta \text{Therms} = \frac{(\text{InputRate}_\text{Base} - \text{InputRate}_\text{EE}) \times (\text{Duty} \times \text{Hours})}{100,000}
\]

Where:

\(\text{InputRate}_\text{Base}\) = Energy input rate of baseline rotisserie oven (Btu/hr)

\(^{111}\)Lifecycle determined from Food Service Technology Center Gas Oven Life-Cycle Cost Calculator.
\[\text{InputRate}_{\text{EE}} = \text{Energy input rate of infrared rotisserie oven (Btu/hr)}\]

\[\text{InputRate}_{\text{EE}} = \text{Custom of if unknown, use 90,000 Btu/hr}^{113}\]

\[\text{Duty} = \text{Duty cycle of rotisserie oven (\%)}\]

\[\text{Duty} = \text{Custom or if unknown, use 60\%}^{115}\]

\[\text{Hours} = \text{Typical operating hours of rotisserie oven}\]

\[\text{Hours} = \text{Custom or if unknown, use 2,496 hours}^{116}\]

\[100,000 = \text{Btu to therms conversion factor}\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IROV-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

---

113 Median rated energy input for rotisserie ovens from FSTC Oven Technology Assessment, Table 7.2
http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

114 Infrared energy input rate calculated based on efficient energy input rate of 50,000 Btu/hr, baseline cooking efficiency of 25\%, and infrared cooking efficiency of 45\%. Efficiencies and rates derived from FSTC Gas Rotisserie Oven Test Reports and FSTC Oven Technology Assessment.

115 Duty cycle from Food Service Technology Center Oven Technical Assessment, Table 7.2

116 Typical operating hours based on oven operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Oven Technical Assessment, Table 7.2
4.2.14 Infrared Salamander Broiler

DESCRIPTION
This measure applies to natural gas fired high efficiency salamander broilers utilizing infrared burners installed in a commercial kitchen.

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

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be a new natural gas salamander broiler with infrared burners.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is an existing natural gas salamander broiler without infrared burners.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 12 years.\(^{117}\)

DEEMED MEASURE COST
The incremental capital cost for this measure is $1000.\(^{118}\)

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

---

**Algorithm**

**ELECTRIC ENERGY SAVINGS**
N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**
N/A

**NATURAL GAS ENERGY SAVINGS**
Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 240 therms, based on defaults.

\[
\Delta \text{Therms} = \frac{(\text{InputRate}_{\text{Base}} - \text{InputRate}_{\text{EE}}) \times (\text{Duty} \times \text{Hours})}{100,000}
\]

\(^{117}\) Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

\(^{118}\) See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.
Where:

\[
\text{InputRate}_{\text{Base}} = \text{Rated energy input rate of baseline salamander broiler (Btu/hr)} \\
= 38,500 \text{ Btu/hr}^{119} \\
\text{InputRate}_{\text{EE}} = \text{Rated energy input rate of infrared salamander broiler (Btu/hr)} \\
= \text{Custom or if unknown, use 24,750 Btu/hr}^{120} \\
\text{Duty} = \text{Duty cycle of salamander broiler (\%)} \\
= \text{Custom or if unknown, use 70\%}^{121} \\
\text{Hours} = \text{Typical operating hours of salamander broiler} \\
= \text{Custom or if unknown, use 2,496 hours}^{122} \\
\text{100,000} = \text{Btu to therms conversion factor}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IRBL-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

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\(^{119}\) Median rated energy input for salamander broilers from FSTC Broiler Technology Assessment, Table 4.3 http://www.fishnick.com/equipment/techassessmen t/4_broilers.pdf

\(^{120}\) Calculated energy input rate based on baseline energy input rate of 38,500 Btu/hr, baseline cooking efficiency of 22.5\%, and infrared cooking efficiency of 35\%

\(^{121}\) Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

\(^{122}\) Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3
4.2.15 Infrared Upright Broiler

**DESCRIPTION**
This measure applies to natural gas fired high efficiency upright broilers utilizing infrared burners and installed in a commercial kitchen.
This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**
To qualify for this measure the installed equipment must be a new natural gas upright broiler with infrared burners.

**DEFINITION OF BASELINE EQUIPMENT**
The baseline equipment is an existing natural gas upright broiler without infrared burners.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The expected measure life is assumed to be 12 years.\(^{123}\)

**DEEMED MEASURE COST**
The incremental capital cost for this measure is $4400.\(^ {124}\)

**LOADSHAPE**
N/A

**COINCIDENCE FACTOR**
N/A

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**
N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**
N/A

**NATURAL GAS ENERGY SAVINGS**
Custom calculation below based on Food Service Technology Center calculator, otherwise use deemed value of 943 therms based on default values.

\[
\Delta \text{Therms} = \frac{(InputRate_{Base} - InputRate_{EE}) \times (Duty \times Hours)}{100,000}
\]

---

\(^{123}\) Lifecycle determined from Food Service Technology Center Gas Broiler Life-Cycle Cost Calculator and from FSTC Broiler Technology Assessment.

Where:

\[
\text{InputRate}_{\text{Base}} = \text{Rated energy input rate of baseline upright broiler (Btu/hr)} \\
= 144,000 \text{ Btu/hr}^{125}
\]

\[
\text{InputRate}_{\text{EE}} = \text{Rated energy input rate of infrared upright broiler (Btu/hr)} \\
= \text{Custom or if unknown, use 90,000 Btu/hr}^{126}
\]

\[
\text{Duty} = \text{Duty cycle of upright broiler (\%)} \\
= \text{Custom or if unknown, use 70}\%^{127}
\]

\[
\text{Hours} = \text{Typical operating hours of upright broiler} \\
= \text{Custom or if unknown, use 2,496 hours}^{128}
\]

\[
100,000 = \text{Btu to therms conversion factor}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-FSE-IRUB-V02-180101**

**REVIEW DEADLINE: 1/1/2024**

---

125 Baseline energy input rate calculated based on efficient energy input rate of 90,000 Btu/hr, baseline cooking efficiency of 25%, and infrared cooking efficiency of 40%

126 Median rated energy input for upright broilers from FSTC Broiler Technology Assessment, Table 4.3


127 Duty cycle from Food Service Technology Center Broiler Technical Assessment, Table 4.3

128 Typical operating hours based on broiler operating schedule of 8 hours per day, 6 days per week, 52 weeks per year, provided in Food Service Technology Center Broiler Technical Assessment, Table 4.3
4.2.16 Kitchen Demand Ventilation Controls

**DESCRIPTION**

Installation of commercial kitchen demand ventilation controls that vary the ventilation based on cooking load and/or time of day.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a control system that varies the exhaust rate of kitchen ventilation (exhaust and/or makeup air fans) based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a new temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed accordingly.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is kitchen ventilation that has constant speed ventilation motor.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 years.\(^{129}\)

**DEEMED MEASURE COST**

The incremental capital cost for this measure is\(^{130}\)

<table>
<thead>
<tr>
<th>Measure Category</th>
<th>Incremental Cost $/HP of fan</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVC Control Retrofit</td>
<td>$1,988</td>
</tr>
<tr>
<td>DVC Control New</td>
<td>$1,000</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

Loadshape C23 - Commercial Ventilation

**COINCIDENCE FACTOR**

The measure has deemed peak kW savings therefore a coincidence factor does not apply.

---

**CALCULATION OF SAVINGS**

Annual energy use was based on monitoring results from five different types of sites, as summarized in PG&E Food Service Equipment work paper.

\(^{129}\) PG&E Workpaper: Commercial Kitchen Demand Ventilation Controls-Electric, 2004 - 2005

\(^{130}\) Ibid.
**Electric Energy Savings**

kWh savings are assumed to be 4966 kWh per horsepower of the fan\(^{131}\)

**Summer Coincident Peak Demand Savings**

kW savings are assumed to be 0.68 kW per horsepower of the fan\(^{132}\)

**Natural Gas Energy Savings**

\[
\Delta \text{Therms} = \text{CFM} \times \text{HP} \times \frac{\text{Annual Heating Load}}{(\text{Eff}(\text{heat}) \times 100,000)}
\]

Where:

- CFM = the average airflow reduction with ventilation controls per hood
  - 430 cfm/HP\(^{133}\)
- HP = actual if known, otherwise assume 7.75 HP\(^{134}\)
- Annual Heating Load = Annual heating energy required to heat fan exhaust make-up air, Btu/CFM
- Eff(heat) = Heating Efficiency
  - actual if known, otherwise assume 80%\(^{136}\)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Annual Heating Load, Btu/CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>154,000</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>144,000</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>132,000</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>102,000</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>104,000</td>
</tr>
</tbody>
</table>

100,000 = conversion from Btu to Therm

\(^{131}\) Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

\(^{132}\) Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

\(^{133}\) Based on data provided in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009. See 'Kitchen DCV.xls' for details.

\(^{134}\) Average of units in PGE Workpaper, Commercial Kitchen Demand Ventilation Controls, PGECOFST116, June 1, 2009.

\(^{135}\) Food Service Technology Center Outside Air Load Calculator, [http://www.fishnick.com/ventilation/oalc/oac.php](http://www.fishnick.com/ventilation/oalc/oac.php), with inputs of one cfm, and hours from Commercial Kitchen Demand Ventilation Controls (Average 17.8 hours a day 4.45 am to 10.30 pm). Savings for Rockford, Chicago, and Springfield were obtained from the calculator; values for Belleville and Marion were obtained by using the average savings per HDD from the other values.

EXAMPLE
For example, a kitchen hood in Rockford, IL with a 7.75 HP ventilation motor
\[ \Delta \text{Therms} = 430 \times 7.75 \times 154,000 / (0.80 \times 100,000) \]
\[ = 6,415 \text{ Therms} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-FSE-VENT-V03-160601

REVIEW DEADLINE: 1/1/2021
4.2.17 Pasta Cooker

**DESCRIPTION**

This measure applies to natural gas fired dedicated pasta cookers as determined by the manufacturer and installed in a commercial kitchen.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a new natural gas fired pasta cooker.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is an existing natural gas fired stove where pasta is cooked in a pan.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12\textsuperscript{137}.

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $2400\textsuperscript{138}.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

The annual natural gas energy savings from this measure is a deemed value equaling 1380 Therms\textsuperscript{139}.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A


\textsuperscript{138}Ibid.

\textsuperscript{139}See ‘Arkansas Deemed TRM Table for GasFoodService.xls’ from v3.0 Arkansas Technical Reference Manual.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-FSE-PCOK-V02-180101

REVIEW DEADLINE: 1/1/2024
4.2.18 Rack Oven - Double Oven

**DESCRIPTION**
This measure applies to natural gas fired high efficiency rack oven - double oven installed in a commercial kitchen. This measure was developed to be applicable to the following program types: TOS. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**
To qualify for this measure the installed equipment must be a new natural gas rack oven – double oven with a baking efficiency $\geq 50\%$ utilizing ASTM standard 2093.

**DEFINITION OF BASELINE EQUIPMENT**
The baseline equipment is an existing natural gas rack oven – double oven with a baking efficiency $< 50\%.$

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The expected measure life is assumed to be 12 years.$^{140}$

**DEEMED MEASURE COST**
The incremental capital cost for this measure is $3000.$$^{141}$

**LOADSHAPE**
N/A

**COINCIDENCE FACTOR**
N/A

### Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**
N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**
N/A

**NATURAL GAS ENERGY SAVINGS**
Custom calculation below, otherwise use deemed value of 1930 therms based on default values.$^{142}$

---

$^{140}$ Lifecycle determined from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator and from FSTC Oven Technology Assessment.


$^{142}$ Assumptions derived from Food Service Technology Center Gas Rack Oven Life-Cycle Cost Calculator, FSTC Oven Technology Assessment (http://www.fishnick.com/equipment/techassessment/7_ovens.pdf), and from FSTC Gas Double Rack Oven Test Reports.
\[ \Delta \text{Therms} = \text{InputRate} \times (\text{BakingEfficiency}_{\text{EE}} - \text{BakingEfficiency}_{\text{Base}}) \times \text{Duty} \times \text{Hours} \times \frac{1}{100,000} \]

Where:

- **InputRate** = Input energy rate of rack oven – double oven
  - Custom or if unknown, 275,000 Btu/hr\(^{143}\)
- **BakingEfficiency\(_{\text{EE}}\)** = Baking efficiency of energy efficiency rack oven – double oven
  - Custom or if unknown, use 55\(^{144}\)
- **BakingEfficiency\(_{\text{Base}}\)** = Baking efficiency of baseline rack oven – double oven
  - Custom or if unknown, 30\%
- **Duty** = Duty cycle of double rack oven (%)
  - Custom or if unknown, use 75\(^{145}\)
- **Hours** = Average daily hours of operation
  - Custom or if unknown, use 3,744 hours\(^{146}\)
- **100,000** = Btu to therms conversion factor

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE CI-FSE-RKOV-VO2-180101**

**REVIEW DEADLINE: 1/1/2024**

\(^{143}\) Median rated energy input for rack ovens from FSTC Oven Technology Assessment, http://www.fishnick.com/equipment/techassessment/7_ovens.pdf

\(^{144}\) Average baking efficiency of double rack oven from FSTC Gas Double Rack Oven Test Reports.

\(^{145}\) Duty cycle from FSTC Gas Double Rack Oven Test Reports on various double rack ovens.

\(^{146}\) Typical operating hours based on oven operating schedule of 12 hours per day, 6 days per week, 52 weeks per year, provided in FSTC Gas Double Rack Oven Test Reports on various double rack ovens.
4.2.19 ENERGY STAR Electric Convection Oven

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. Energy savings estimates are for ovens using full size (18” x 36”) sheet pans.

This measure was developed to be applicable to the following program types; TOS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is assumed to be an ENERGY STAR qualified electric convection oven.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a standard convection oven with a heavy load efficiency of 65%.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 12 years.147

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $800 for half size units and $1000 for full size148

LOADSHAPE

Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR

Summer Peak Coincidence Factor for measure is provided below for different building type149:

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.40</td>
</tr>
</tbody>
</table>


148 Based on data from the Regional Technical Forum for the Northwest Council (http://rtf.nw council.org/measures/com/ComCookingConvectionOven_v2_0.xlsm) using actual list prices for 23 units from 2012, see “ComCookingConvectionOven_v2_0.xlsm”.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta kWh = kWh_{base} - kWh_{eff} \]

\[ kWh = \left[ \left( LB \times E_{FOOD/EFF} \right) + \left( \text{IDLE} \times (HOURS_{DAY} - \text{LB/PC} - \text{PRE_TIME}/60) \right) + \text{PRE_ENERGY} \right] \times DAYS \]

Where:

- \( kWh_{base} \) = 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
- \( HOURS_{DAY} \) = daily operating hours
- \( PRE_{TIME} \) = Preheat time (min/day), the amount of time it takes a steamer to reach operating temperature when turned on
  - Default = 15 min/day
- \( E_{FOOD} \) = ASTM Energy to Food (kWh/lb); the amount of energy absorbed by the food during cooking, per pound of food
  - Default = 0.0732
- \( LB \) = pounds of food cooked per day (lb/day)

<table>
<thead>
<tr>
<th>Type of Food Service</th>
<th>HOURS_{DAY}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food, limited menu</td>
<td>4</td>
</tr>
<tr>
<td>Fast Food, expanded menu</td>
<td>5</td>
</tr>
<tr>
<td>Pizza</td>
<td>8</td>
</tr>
<tr>
<td>Full Service, limited menu</td>
<td>8</td>
</tr>
<tr>
<td>Full Service, expanded menu</td>
<td>7</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>6</td>
</tr>
<tr>
<td>Unknown</td>
<td>6^{151}</td>
</tr>
<tr>
<td>Custom</td>
<td>Varies</td>
</tr>
</tbody>
</table>

- \( DAYS \) = Days per year of operation
- Actual, default = 365^{152}

**FOOD SERVICE TECHNOLOGY CENTER (FSTC). Default value from life cycle cost calculator.**


\[^{151}\text{Unknown is average of other locations}\]

\[^{152}\text{Food Service Technology Center (FSTC). Default value from life cycle cost calculator.}\]

\[^{153}\text{Food Service Technology Center (2002). Commercial Cooking Appliance Technology Assessment. Prepared by Don Fisher.}\]

\[^{154}\text{American Society for Testing and Materials. Industry standard for Commercial Ovens}\]
EFF = Heavy load cooking energy efficiency (%). See table below.
IDLE = Idle energy rate. See table below.
PC = Production capacity (lbs/hr). See table below.
PRE\textsubscript{ENERGY} = Preheat energy (kWh/day). See table below.

Performance Metrics: Baseline and Efficient Values

<table>
<thead>
<tr>
<th>Metric</th>
<th>Baseline Model \textsuperscript{156}</th>
<th>Energy Efficient Model \textsuperscript{157}</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRE\textsubscript{ENERGY} (kWh)</td>
<td>1.5</td>
<td>1</td>
</tr>
<tr>
<td>IDLE (kW)</td>
<td>2</td>
<td>Actual, default = 1.0</td>
</tr>
<tr>
<td>EFF</td>
<td>65%</td>
<td>Actual, default = 74%</td>
</tr>
<tr>
<td>PC (lb/hr)</td>
<td>70</td>
<td>Actual, default = 79</td>
</tr>
</tbody>
</table>

EXAMPLE

Using defaults provided above, the savings for a ENERGY STAR Electric Convection Oven in unknown location are:

\[
\begin{align*}
\text{kWh}_{\text{base}} &= (100 \times 0.0732/0.65) + (2 \times (6 - 100/70 - 15/60)) + 1.5 \times 365 \\
&= 7,813 \text{ kWh} \\
\text{kWh}_{\text{eff}} &= (100 \times 0.0732/0.74) + (1 \times (6 - 100/79 - 15/60)) + 1.0 \times 365 \\
&= 5,612 \text{ kWh} \\
\Delta \text{kWh} &= \text{kWh}_{\text{base}} - \text{kWh}_{\text{eff}} \\
&= 7,813 - 5,612 \\
&= 2200 \text{ kWh}
\end{align*}
\]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta \text{kW} = (\Delta \text{kWh} / (\text{HOURS} \times \text{DAYS})) \times \text{CF}
\]

Where:

\[
\Delta \text{kWh} = \text{Annual energy savings (kWh)}
\]

\textsuperscript{155} Food Service Technology Center (FSTC). Default value from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php
\textsuperscript{156} Food Service Technology Center (FSTC). Default values from life cycle cost calculator. http://www.fishnick.com/saveenergy/tools/calculators/eovencalc.php
\textsuperscript{157} Average ratings of units on ENERGY STAR qualified list as of 10/2014. Preheat energy is not provided so default is provided based on FSTC life cycle cost calculator.
CF = Summer Peak Coincidence Factor for measure is provided below for different building type.  

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.40</td>
</tr>
</tbody>
</table>

**EXAMPLE**

Using defaults provided above, the savings for a ENERGY STAR Electric Convection Oven in unknown location are:

\[
\Delta kW = \frac{2200}{(6 \times 365)} \times 0.40 = 0.40
\]

**FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION**  
N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**  
N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**  
N/A

**MEASURE CODE CI-FSE-ECON-VO1-150601**

**REVIEW DEADLINE: 1/1/2022**

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4.3 Hot Water

4.3.1 Storage Water Heater

**DESCRIPTION**

This measure is for upgrading from minimum code to a high efficiency storage-type water heater. Storage water heaters are used to supply hot water for a variety of commercial building types. Storage capacities vary greatly depending on the application. Large consumers of hot water include (but not limited to) industries, hotels/motels and restaurants.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

The minimum specifications of the high efficiency equipment should be defined by the programs.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is assumed to be a new standard water heater of same type as existing, meeting the Federal Standard for <75,000 Btuh units and IECC 2015 for all others. If existing type is unknown, assume Gas Storage Water Heater.

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Sub Category</th>
<th>Federal Standard Minimum Efficiency&lt;sup&gt;159&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage Water Heaters ≤ 75,000 Btu/h</td>
<td>≤55 gallon tanks</td>
<td>0.675 – (0.0015 * Rated Storage Volume in Gallons) EF</td>
</tr>
<tr>
<td></td>
<td>&gt;55 gallon tanks</td>
<td>0.8012 – (0.00078 * Rated Storage Volume in Gallons) EF</td>
</tr>
<tr>
<td>Gas Storage Water Heaters &gt; 75,000 Btu/h</td>
<td>&lt; 4000 Btu/h/gal</td>
<td>80% Et Standby Loss: (Q/800 + 110√V)</td>
</tr>
<tr>
<td>Electric Water Heaters ≤ 75,000 Btu/h</td>
<td>≤55 gallon tanks</td>
<td>0.96 – (0.0003 * rated volume in gallons) EF</td>
</tr>
<tr>
<td></td>
<td>&gt;55 gallon tanks</td>
<td>2.057 – (0.00113 * rated volume in gallons) EF</td>
</tr>
<tr>
<td>Electric Water Heaters &gt; 75,000 Btu/h</td>
<td>≤12 kW</td>
<td>0.97 – (0.00132 * rated volume in gallons) EF</td>
</tr>
<tr>
<td></td>
<td>&gt;12 kW</td>
<td>Standby Loss: 0.30 + 27/Vm (%/hr)</td>
</tr>
</tbody>
</table>

V= Rated volume in gallons, Vm = measured volume in gallons.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 Years<sup>161</sup>

**DEEMED MEASURE COST**

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available<sup>162</sup>:

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Category</th>
<th>Install Cost</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage Water Heaters ≤ 75,000 Btu/h, ≤55 Gallons</td>
<td>Baseline</td>
<td>$616</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Efficient</td>
<td>$1,055</td>
<td>$440</td>
</tr>
</tbody>
</table>

<sup>159</sup> ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

<sup>160</sup> It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline.

<sup>161</sup> DEER 08, EUL_Summary_10-1-08.xls.

<sup>162</sup> Cost information is based upon data from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. See “NR HW Heater_WA017_MCS Results Matrix - Volume I.xls” for more information.
### Illinois Statewide Technical Reference Manual – 4.3.1 Storage Water Heater

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Category</th>
<th>Install Cost</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage Water Heaters</td>
<td>0.80 Et</td>
<td>$4,886</td>
<td>N/A</td>
</tr>
<tr>
<td>75,000 Btu/h</td>
<td>0.83 Et</td>
<td>$5,106</td>
<td>$220</td>
</tr>
<tr>
<td></td>
<td>0.84 Et</td>
<td>$5,299</td>
<td>$413</td>
</tr>
<tr>
<td></td>
<td>0.85 Et</td>
<td>$5,415</td>
<td>$529</td>
</tr>
<tr>
<td></td>
<td>0.86 Et</td>
<td>$5,532</td>
<td>$646</td>
</tr>
<tr>
<td></td>
<td>0.87 Et</td>
<td>$5,648</td>
<td>$762</td>
</tr>
<tr>
<td></td>
<td>0.88 Et</td>
<td>$5,765</td>
<td>$879</td>
</tr>
<tr>
<td></td>
<td>0.89 Et</td>
<td>$5,882</td>
<td>$996</td>
</tr>
<tr>
<td></td>
<td>0.90 Et</td>
<td>$6,021</td>
<td>$1,135</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank Size</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 gallons</td>
<td>$1050</td>
</tr>
<tr>
<td>80 gallons</td>
<td>$1050</td>
</tr>
<tr>
<td>100 gallons</td>
<td>$1950</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

For electric hot water heaters, use Loadshape C02 - Non-Residential Electric DHW.

**COINCIDENCE FACTOR**

The coincidence factor is assumed to be 0.925 \(^{164}\).

### Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Electric energy savings are calculated for electric storage water heaters per the equations given below.

Electric units ≤12 kW:

\[
\Delta kWH = \frac{(T_{out} - T_{in}) \times HotWaterUse_{Gallon} \times \gamma_{Water} \times 1 \times \left( \frac{1}{EF_{elecbase}} - \frac{1}{EF_{Eff}} \right)}{3412}
\]

Where:

- \( T_{out} \) = Tank temperature
- \( = 125^\circ F \)
- \( T_{in} \) = Incoming water temperature from well or municipal system
- \( = 54^\circ F \)^{165}

---


\(^{164}\) Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads, US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html

---
HotWaterUse\textsubscript{Gallon} = Estimated annual hot water consumption (gallons)
= Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per usable storage tank capacity
   = Capacity * Consumption/cap

   Where:
   
   Capacity = Usable capacity of hot water storage tank in gallons
   = Actual

   Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:\textsuperscript{166}

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Consumption/Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>528</td>
</tr>
<tr>
<td>Education</td>
<td>568</td>
</tr>
<tr>
<td>Grocery</td>
<td>528</td>
</tr>
<tr>
<td>Health</td>
<td>788</td>
</tr>
<tr>
<td>Large Office</td>
<td>511</td>
</tr>
<tr>
<td>Large Retail</td>
<td>528</td>
</tr>
<tr>
<td>Lodging</td>
<td>715</td>
</tr>
<tr>
<td>Other Commercial</td>
<td>341</td>
</tr>
<tr>
<td>Restaurant</td>
<td>622</td>
</tr>
<tr>
<td>Small Office</td>
<td>511</td>
</tr>
<tr>
<td>Small Retail</td>
<td>528</td>
</tr>
<tr>
<td>Warehouse</td>
<td>341</td>
</tr>
<tr>
<td>Nursing</td>
<td>672</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>894</td>
</tr>
</tbody>
</table>

2. Consumption per unit area by building type
   = (Area/1000) * Consumption/1,000 sq.ft.

   Where:
   
   Area = Area in sq.ft that is served by DHW boiler
   = Actual

   Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:\textsuperscript{168}

\textsuperscript{166} Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

\textsuperscript{167} According to CBEC 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

\textsuperscript{168} Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL.
### Storage Water Heater

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Consumption/1,000 sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>4,594</td>
</tr>
<tr>
<td>Education</td>
<td>7,285</td>
</tr>
<tr>
<td>Grocery</td>
<td>697</td>
</tr>
<tr>
<td>Health</td>
<td>24,540</td>
</tr>
<tr>
<td>Large Office</td>
<td>1,818</td>
</tr>
<tr>
<td>Large Retail</td>
<td>1,354</td>
</tr>
<tr>
<td>Lodging</td>
<td>29,548</td>
</tr>
<tr>
<td>Other Commercial</td>
<td>3,941</td>
</tr>
<tr>
<td>Restaurant</td>
<td>44,439</td>
</tr>
<tr>
<td>Small Office</td>
<td>1,540</td>
</tr>
<tr>
<td>Small Retail</td>
<td>6,111</td>
</tr>
<tr>
<td>Warehouse</td>
<td>1,239</td>
</tr>
<tr>
<td>Nursing</td>
<td>30,503</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>15,434</td>
</tr>
</tbody>
</table>

γ\(\text{Water}\) = Specific weight capacity of water (lb/gal)

\(\gamma = 8.33 \text{ lbs/gal}\)

1 = Specific heat of water (Btu/lb.°F)

\(E_{\text{F base}}\) = Rated efficiency of baseline water heater expressed as Energy Factor (EF);

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Sub Category</th>
<th>Federal Standard Minimum Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Water Heaters ≤ 75,000 Btu/h</td>
<td>≤55 gallon tanks</td>
<td>0.96 – (0.0003 * rated volume in gallons) EF</td>
</tr>
<tr>
<td></td>
<td>&gt;55 gallon tanks 171</td>
<td>2.057 – (0.00113 * rated volume in gallons) EF</td>
</tr>
<tr>
<td>Electric Water Heaters &gt; 75,000 Btu/h</td>
<td>≤12 kW</td>
<td>0.97 – (0.00132 * rated volume in gallons) EF</td>
</tr>
<tr>
<td></td>
<td>&gt; 12kW</td>
<td>N/A (For &gt;12 kW Units see below)</td>
</tr>
</tbody>
</table>

\(E_{\text{F eff}}\) = Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (E_t)

= Actual

3412 = Converts Btu to kWh

For example, for a 200,000 Btu/h, 150 gallon, 90% Thermal Efficiency storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft² restaurant:

\[\Delta \text{kWh} = ((125 – 54) \times (1,500/1,000) \times 44,439) \times 8.33 \times 1 \times (1/0.8 - 1/0.9))/3412\]

\[\Delta \text{kWh} = 1,605 \text{kWh}\]

Electric units > 12kW:

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White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.

169 According to CBECs 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.

170 ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.

171 It is assumed that tanks <75,000 Btu/h and >55 gallons will not be eligible measures due to the high baseline.
\[ \Delta kWh = \frac{(T_{out} - T_{air}) \times V \times \gamma_{Water} \times 1 \times (S_{Lelecbase} - S_{Eff}) \times 8766}{3412} \]

- \( T_{air} \) = Ambient Air Temperature
- \( V \) = Rated tank volume in gallons
- \( S_{Lelecbase} \) = Standby loss of electric baseline unit (%/hr)
  \[ S_{Lelecbase} = 0.30 + \frac{27}{V} \]
- \( S_{Eff} \) = Nameplate standby loss of new water heater, in BTU/h
- 8766 = Hours per year

For example, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

\[ S_{Lelecbase} = 0.30 + \frac{27}{100} = 0.57\%/hr \]

\[ \Delta kWh = \frac{((125 - 70) \times 100 \times 8.33 \times 1 \times (0.57 - 0.5)) \times 8766}{3412} \]
\[ \Delta kWh = 8,239 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta W = \frac{\Delta kWh}{Hours \times CF} \]

Where:

- \( Hours \) = Full load hours of water heater
  \[ Hours = 6461 \]  
- \( CF \) = Summer Peak Coincidence Factor for measure
  \[ CF = 0.925 \]

For example, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

\[ \Delta kW = \frac{8,239}{6,461 \times 0.925} \]
\[ \Delta kW = 1.18 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

Natural gas energy savings are calculated for natural gas storage water heaters per the equations given below.

\[ \Delta T_{Therms} = \frac{(T_{out} - T_{in}) \times HotWaterUse_{Gallon} \times \gamma_{Water} \times 1 \times \left( \frac{1}{E_{gasbase}} - \frac{1}{E_{Eff}} \right)}{100,000} \]

Where:

---

172 Full load hours assumption based on Wh/Max W Ratio from Itron eShape data for Missouri, calibrated to Illinois loads.
173 Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads.
100,000 = Converts Btu to Therms

$\text{EF}_{\text{gas base}}$ = Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency ($E_t$);

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Sub Category</th>
<th>Federal Standard Minimum Efficiency(^{174})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage Water Heaters ≤ 75,000 Btu/h</td>
<td>≤55 gallon tanks</td>
<td>0.675 – (0.0015 * Rated Storage Volume in Gallons) EF</td>
</tr>
<tr>
<td></td>
<td>&gt;55 gallon tanks</td>
<td>0.8012 – (0.00078 * Rated Storage Volume in Gallons) EF</td>
</tr>
<tr>
<td>Gas Storage Water Heaters &gt; 75,000 Btu/h</td>
<td>&lt; 4000 Btu/h/gal</td>
<td>80% $E_t$</td>
</tr>
</tbody>
</table>

### Additional Standby Loss Savings

Gas Storage Water Heaters >75,000 Btu/h can claim additional savings due to lower standby losses.

$$\Delta \text{Therms}_{\text{standby}} = \frac{(SL_{\text{gas base}} - SL_{\text{eff}}) \times 8766}{100,000}$$

Where:

- $SL_{\text{gas base}}$ = Standby loss of gas baseline unit (Btu/h)
- $Q = \frac{Q}{800} + 110\sqrt{V}$
- $Q$ = Nameplate input rating in Btu/h
- $V$ = Rated volume in gallons
- $SL_{\text{eff}}$ = Nameplate standby loss of new water heater, in Btu/h
- 8766 = Hours per year

For example, for a 200,000 Btu/h, 150 gallon, 90% Thermal Efficiency storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft\(^2\) restaurant:

$$\Delta \text{Therms} = ((125 - 54) \times ((1,500/1,000) \times 44,439) \times 8.33 \times 1 \times (1/0.8 - 1/0.9)/100,000$$

$$\Delta \text{Therms} = 54.8 \text{ Therms}$$

$$\Delta \text{Therms}_{\text{standby}} = (((200000/800 + 110 \times \sqrt{150}) - 1079) \times 8766)/100,000$$

$$\Delta \text{Therms}_{\text{standby}} = 49.8 \text{ Therms}$$

$$\Delta \text{Therms}_{\text{Total}} = 54.8 + 49.8$$

$$\Delta \text{Therms}_{\text{Total}} = 104.6 \text{ Therms}$$

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

\(^{174}\) ≤75,000 Btu/h Storage Water Heater and <200,000 Btu/h Tankless Water Heater Federal Standard is DOE Standard 10 CFR 430.32(d). All other standards are from 10 CFR 431.110.
MEASURE CODE: CI-HWE-STWH-V03-180101

REVIEW DEADLINE: 1/1/2019
4.3.2 Low Flow Faucet Aerators

DESCRIPTION
This measure relates to the direct installation of a low flow faucet aerator in a commercial building. Expected applications include small business, office, restaurant, or motel. Health care-specific inputs are defined for Laminar Flow Restrictor (LFR) devices. For multifamily or senior housing, the residential low flow faucet aerator should be used.

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

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be an energy efficient faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. For LFR devices, the installed equipment must be a device rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

DEFINITION OF BASELINE EQUIPMENT
The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or more, or a standard kitchen faucet aerator rated at 2.75 GPM or more. For LFR devices, the baseline condition is assumed to be no aerator at all, due to the contamination risk caused by faucet aerators in health care facilities and the baseline flow rate is assumed to be 3.74 GPM. Note if flow rates are measured, for example through a Direct Install program, then actual baseline flow rates should be used as opposed to the deemed values.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 9 years.

DEEMED MEASURE COST
The full install cost (including labor) for this measure is $8 or program actual. For LFRs, the incremental cost is $14.27 or program actual.

LOADSHAPE
Loadshape C02 - Commercial Electric DHW

COINCIDENCE FACTOR
The coincidence factor for this measure is dependent on building type as presented below.

175 Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.
177 Direct-install price per faucet assumes cost of aerator and install time. (2011, Market research average of $3 and assess and install time of $5 (20min @ $15/hr)
178 Direct install price per faucet assumes cost of LFR ($7.27) and install time ($7) (Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015).
Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

**NOTE THESE SAVINGS ARE PER FAUCET RETROFITTED**\(^{179}\).

\[
\Delta \text{kWh} = \%\text{ElectricDHW} \times ((\text{GPM\_base} - \text{GPM\_low})/\text{GPM\_base}) \times \text{Usage} \times \text{EPG\_electric} \times \text{ISR}
\]

Where:

\(\%\text{ElectricDHW}\) = proportion of water heating supplied by electric resistance heating

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Electric_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Fossil Fuel</td>
<td>0%</td>
</tr>
</tbody>
</table>

\(\text{GPM\_base}\) = Average flow rate, in gallons per minute, of the baseline faucet “as-used”

= 1.39\(^{180}\) or custom based on metering studies\(^{181}\) or if measured during DI:

= Measured full throttle flow \(\times 0.83\) throttling factor\(^{182}\)

Baseline for LFRs\(^{183}\):

= 3.74 \(\times 0.83 = 3.10\)

\(\text{GPM\_low}\) = Average flow rate, in gallons per minute, of the low-flow faucet aerator “as-used”

= 0.94\(^{184}\) or custom based on metering studies\(^{185}\) or if measured during DI:

= Rated full throttle flow \(\times 0.95\) throttling factor\(^{186}\)

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\(^{179}\) This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture. Due to the distribution of water consumption by fixture type, as well as the different number of fixtures in a building, several variables must be incorporated.


\(^{181}\) Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.


\(^{183}\) Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

\(^{184}\) Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7. This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

\(^{185}\) Measurement should be based on actual average flow consumed over a period of time rather than a onetime spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

For LFRs\textsuperscript{187}:

\[ = 2.2 \times 0.95 = 2.09 \]

**Usage**

- Estimated usage of mixed water (mixture of hot water from water heater line and cold water line) per faucet (gallons per year)

- If data is available to provide a reasonable custom estimate it should be used, if not use the following defaults (or substitute custom information in to the calculation):

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Gallons hot water per unit per day\textsuperscript{188} (A)</th>
<th>Unit</th>
<th>Estimated % hot water from Faucets\textsuperscript{189} (B)</th>
<th>Multiplier\textsuperscript{190} (C)</th>
<th>Unit</th>
<th>Days per year (D)</th>
<th>Annual gallons mixed water per faucet ( A \times B \times C \times D )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Office</td>
<td>1</td>
<td>person</td>
<td>100%</td>
<td>10</td>
<td>employees per faucet</td>
<td>250</td>
<td>2,500</td>
</tr>
<tr>
<td>Large Office</td>
<td>1</td>
<td>person</td>
<td>100%</td>
<td>45</td>
<td>employees per faucet</td>
<td>250</td>
<td>11,250</td>
</tr>
<tr>
<td>Fast Food Rest</td>
<td>0.7</td>
<td>meal/day</td>
<td>50%</td>
<td>75</td>
<td>meals per faucet</td>
<td>365</td>
<td>9,581</td>
</tr>
<tr>
<td>Sit-Down Rest</td>
<td>2.4</td>
<td>meal/day</td>
<td>50%</td>
<td>36</td>
<td>meals per faucet</td>
<td>365</td>
<td>15,768</td>
</tr>
<tr>
<td>Retail</td>
<td>2</td>
<td>employee</td>
<td>100%</td>
<td>5</td>
<td>employees per faucet</td>
<td>365</td>
<td>3,650</td>
</tr>
<tr>
<td>Grocery</td>
<td>2</td>
<td>employee</td>
<td>100%</td>
<td>5</td>
<td>employees per faucet</td>
<td>365</td>
<td>3,650</td>
</tr>
<tr>
<td>Warehouse</td>
<td>2</td>
<td>employee</td>
<td>100%</td>
<td>5</td>
<td>employees per faucet</td>
<td>250</td>
<td>2,500</td>
</tr>
<tr>
<td>Elementary School</td>
<td>0.6</td>
<td>person</td>
<td>50%</td>
<td>50</td>
<td>students per faucet</td>
<td>200</td>
<td>3,000</td>
</tr>
<tr>
<td>Jr High/High School</td>
<td>1.8</td>
<td>person</td>
<td>50%</td>
<td>50</td>
<td>students per faucet</td>
<td>200</td>
<td>9,000</td>
</tr>
<tr>
<td>Health</td>
<td>90</td>
<td>patient</td>
<td>25%</td>
<td>2</td>
<td>Patients per faucet</td>
<td>365</td>
<td>16,425</td>
</tr>
<tr>
<td>Motel</td>
<td>20</td>
<td>room</td>
<td>25%</td>
<td>1</td>
<td>faucet per room</td>
<td>365</td>
<td>1,825</td>
</tr>
<tr>
<td>Hotel</td>
<td>14</td>
<td>room</td>
<td>25%</td>
<td>1</td>
<td>faucet per room</td>
<td>365</td>
<td>1,278</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>employee</td>
<td>100%</td>
<td>20</td>
<td>employees per faucet</td>
<td>250</td>
<td>5,000</td>
</tr>
</tbody>
</table>

\textbf{EPG\_electric}

- Energy per gallon of mixed water used by faucet (electric water heater)

\[ = \frac{(8.33 \times 1.0 \times (\text{WaterTemp} - \text{SupplyTemp}))}{(\text{RE\_electric} \times 3412)} \]

- 0.0795 kWh/gal for Bath, 0.0969 kWh/gal for Kitchen, 0.139 kWh/gal for LFRs, 0.0919 kWh/gal for unknown

\textbf{8.33}

- Specific weight of water (lbs/gallon)

\textbf{1.0}

- Heat Capacity of water (btu/lb \textdegree F)

\textbf{WaterTemp}

- Assumed temperature of mixed water

---

\textsuperscript{187} Using measured flow rate assumption from Workpaper WPSCGNRWH150827A, Laminar Flow Restrictors For Hospitals and Health Care Facilities.

\textsuperscript{188} Table 2-45 Chapter 49, Service Water Heating, 2007 ASHRAE Handbook, HVAC Applications.

\textsuperscript{189} Estimated based on data provided in Appendix E; “Waste Not, Want Not: The Potential for Urban Water Conservation in California”; http://www.pacinst.org/reports/urban_usage/appendix_e.pdf

\textsuperscript{190} Based on review of the Illinois plumbing code (Employees and students per faucet). Retail, grocery, warehouse and health are estimates. Meals per faucet estimated as 4 bathroom and 3 kitchen faucets and average meals per day of 250 (based on California study above) – 250/7 = 36. Fast food assumption estimated.
= 86F for Bath, 93F for Kitchen 91F for Unknown\textsuperscript{191}, 110F for health care facilities\textsuperscript{192}

SupplyTemp = Assumed temperature of water entering building

= 54.1°F \textsuperscript{193}

RE\textsubscript{electric} = Recovery efficiency of electric water heater

= 98% \textsuperscript{194}

3412 = Converts Btu to kWh (Btu/kWh)

ISR = In service rate of faucet aerators dependent on install method as listed in table below\textsuperscript{195}

<table>
<thead>
<tr>
<th>Selection</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install - Deemed</td>
<td>0.95</td>
</tr>
</tbody>
</table>

\textbf{EXAMPLE}

For example, a direct installed kitchen faucet in a large office with electric DHW:

\[ \Delta k\text{Wh} = 1 \times \frac{(1.39 - 0.94)}{1.39} \times 11,250 \times 0.0969 \times 0.95 \]

= 335.3 kWh

For example, a direct installed bathroom faucet in an Elementary School with electric DHW:

\[ \Delta k\text{Wh} = 1 \times \frac{(1.39 - 0.94)}{1.39} \times 3,000 \times 0.0795 \times 0.95 \]

= 73.4 kWh

\textbf{SUMMER COINCIDENT PEAK DEMAND SAVINGS}

\[ \Delta kW = \left( \frac{\Delta k\text{Wh}}{\text{Hours}} \right) \times \text{CF} \]

Where:

\( \Delta k\text{Wh} \) = calculated value above on a per faucet basis

\( \text{Hours} \) = Annual electric DHW recovery hours for faucet use

\( \text{CF} \) = Calculate if usage is custom, if using default usage use:

\[ = (\text{Usage} \times 0.545) / \text{GPH} \]

191 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom \((0.7\times93)+(0.3\times86)=0.91\).

192 Southern California Gas Company, Workpaper WPSCGNRWH150827A Revision #0, September, 2015


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


196 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90°F mixed faucet water.
<table>
<thead>
<tr>
<th>Building Type</th>
<th>Annual Recovery Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Office</td>
<td>24</td>
</tr>
<tr>
<td>Large Office</td>
<td>109</td>
</tr>
<tr>
<td>Fast Food Rest</td>
<td>93</td>
</tr>
<tr>
<td>Sit-Down Rest</td>
<td>153</td>
</tr>
<tr>
<td>Retail</td>
<td>36</td>
</tr>
<tr>
<td>Grocery</td>
<td>36</td>
</tr>
<tr>
<td>Warehouse</td>
<td>24</td>
</tr>
<tr>
<td>Elementary School</td>
<td>29</td>
</tr>
<tr>
<td>Jr High/High School</td>
<td>88</td>
</tr>
<tr>
<td>Health</td>
<td>160</td>
</tr>
<tr>
<td>Motel</td>
<td>18</td>
</tr>
<tr>
<td>Hotel</td>
<td>12</td>
</tr>
<tr>
<td>Other</td>
<td>49</td>
</tr>
</tbody>
</table>

Where:

- **GPH** = Gallons per hour recovery of electric water heater calculated for 85.9°F temp rise (140-54.1), 98% recovery efficiency, and typical 12kW electric resistance storage tank.

- **CF** = Coincidence Factor for electric load reduction

- **=** Dependent on building type

---

Calculated as follows: Assumptions for percentage of usage during peak period (1-5pm) were made and then multiplied by 65/365 (65 being the number of days in peak period) and by the number of total annual recovery hours to give an estimate of the number of hours of recovery during peak periods. There are 260 hours in the peak period so the probability you will see savings during the peak period is calculated as the number of hours of recovery during peak divided by 260. See ‘C&I Faucet Aerator.xls’ for details.
EXAMPLE
For example, a direct installed kitchen faucet in a large office with electric DHW:

\[ \Delta k\text{W} = \frac{335.3}{109} \times 0.0288 \]

\[ = 0.0886 \text{ kW} \]

For example, a direct installed bathroom faucet in an Elementary School with electric DHW:

\[ \Delta k\text{W} = \frac{73.4}{29} \times 0.0096 \]

\[ = 0.0243 \text{ kW} \]

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

\[ \Delta \text{Therms} = \%\text{FossilDHW} \times \frac{(GPM_{base} - GPM_{low})}{GPM_{base}} \times \text{Usage} \times \text{EPG}_\text{gas} \times \text{ISR} \]

Where:

\%\text{FossilDHW} = \text{proportion of water heating supplied by fossil fuel heating}

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%\text{Fossil DHW}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Fossil Fuel</td>
<td>100%</td>
</tr>
</tbody>
</table>

\text{EPG}_\text{gas} = \text{Energy per gallon of mixed water used by faucet (gas water heater)}

\[ = (8.33 \times 1.0 \times (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE}_\text{gas} \times 100,000) \]

\[ = 0.00397 \text{ Therm/gal for Bath, 0.00484 Therm/gal for Kitchen, 0.00695 Therm/gal for LFRs, 0.00459 Therm/gal for unknown} \]

Where:

\text{RE}_\text{gas} = \text{Recovery efficiency of gas water heater}

\[ = 67\% \quad ^{198} \]

100,000 = \text{Converts Btus to Therms (Btu/Therm)}

Other variables as defined above.

\[ ^{198} \text{Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87\%. Average of existing units is estimated at 75\%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.} \]
**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[
\Delta \text{gallons} = ((\text{GPM} \_\text{base} - \text{GPM} \_\text{low})/\text{GPM} \_\text{base}) \times \text{Usage} \times \text{ISR}
\]

Variables as defined above

**EXAMPLE**

For example, a direct installed kitchen faucet in a large office with gas DHW:

\[
\Delta \text{Therms} = 1 \times ((1.39 - 0.94)/1.39) \times 11,250 \times 0.00484 \times 0.95 \\
= 16.7 \text{ Therms}
\]

For example, a direct installed bathroom faucet in an Elementary School with gas DHW:

\[
\Delta \text{Therms} = 1 \times ((1.39 - 0.94)/1.39) \times 3,000 \times 0.00397 \times 0.95 \\
= 3.66 \text{ Therms}
\]

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES USED FOR GPM ASSUMPTIONS**

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source ID</td>
<td>Reference</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
</tr>
</tbody>
</table>

**MEASURE CODE:** CI-HWE-LFFA-V07-180101

**REVIEW DEADLINE:** 1/1/2023
4.3.3 Low Flow Showerheads

DESCRIPTION
This measure relates to the direct installation of a low flow showerhead in a commercial building. Expected applications include small business, office, restaurant, or small motel. For multifamily or senior housing, the residential low flow showerhead should be used.

This measure was developed to be applicable to the following program types: DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be an energy efficient showerhead rated at 2.0 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture basis.

DEFINITION OF BASELINE EQUIPMENT
The baseline condition is assumed to be a standard showerhead rated at 2.5 GPM.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 10 years.\(^{199}\)

DEEMED MEASURE COST
The full install cost (including labor) for this measure is $12\(^{200}\) or program actual.

LOADSHAPE
Loadshape C02 - Commercial Electric DHW

COINCIDENCE FACTOR
The coincidence factor for this measure is assumed to be 2.78\(^{201}\).

Algorithm

CALCULATION OF SAVINGS \(^{202}\)

ELECTRIC ENERGY SAVINGS
Note these savings are per showerhead fixture

\(^{199}\) Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family, "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

\(^{200}\) Direct-install price per showerhead assumes cost of showerhead (Market research average of $7 and assess and install time of $5 (20min @ $15/hr)

\(^{201}\) Calculated as follows: Assume 11% showers take place during peak hours (based on: http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282001%29-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

\(^{202}\) Based on excel spreadsheet 120911.xls ...on SharePoint
\[ \Delta kWh = \%\text{ElectricDHW} \times ((\text{GPM\_base} \times \text{L\_base} - \text{GPM\_low} \times \text{L\_low}) \times \text{NSPD} \times 365.25) \times \text{EPG\_electric} \times \text{ISR} \]

Where:

- \%\text{ElectricDHW} = \text{proportion of water heating supplied by electric resistance heating}
  = 1 if electric DHW, 0 if fuel DHW, if unknown assume 16\% \(^{203}\)
- \text{GPM\_base} = \text{Flow rate of the baseline showerhead}
  = 2.67 for Direct-install programs\(^{204}\)
- \text{GPM\_low} = \text{As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaluations deviate from rated flows, see table below:}
- \text{L\_base} = \text{Shower length in minutes with baseline showerhead}
  = 8.20 min\(^ {206}\)
- \text{L\_low} = \text{Shower length in minutes with low-flow showerhead}
  = 8.20 min\(^ {207}\)
- 365.25 = Days per year, on average.
- \text{NSPD} = \text{Estimated number of showers taken per day for one showerhead}
- \text{EPG\_electric} = \text{Energy per gallon of hot water supplied by electric}
  = \left(8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp})\right) / (\text{RE\_electric} \times 3412)
  = \left(8.33 \times 1.0 \times (105 - 54.1)\right) / (0.98 \times 3412)
  = 0.127 \text{ kWh/gal}
- 8.33 = \text{Specific weight of water (lbs/gallon)}
- 1.0 = \text{Heat Capacity of water (btu/lb\(^{-\circ}\text{F}\))}
- \text{ShowerTemp} = \text{Assumed temperature of water}
  = 105\^\circ\text{F} \(^{208}\)

\(^{203}\) Table HC8.9. Water Heating in U.S. Homes in Midwest Region, Divisions, and States, 2009 (RECS)
\(^{204}\) Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above.
\(^{205}\) Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.
\(^{206}\) Representative value from sources 1, 2, 3, 4, 5, and 6 (See Source Table at end of measure section)
\(^{207}\) Set equal to L\_base.
SupplyTemp = Assumed temperature of water entering house
= 54.1°F

RE_electric = Recovery efficiency of electric water heater
= 98%

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead
= Dependant on program delivery method as listed in table below

<table>
<thead>
<tr>
<th>Selection</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install - Deemed</td>
<td>0.98</td>
</tr>
</tbody>
</table>

EXAMPLE

For example, a direct-installed 1.5 GPM showerhead in an office with electric DHW where the number of showers is estimated at 3 per day:

\[
\Delta k\text{Wh} = 1 \times (\left(2.67 \times 8.20\right) - \left(1.5 \times 8.20\right)) \times 3 \times 365.25 \times 0.127 \times 0.98
\]

\[
\Delta k\text{Wh} = 1308.4 \text{ kWh}
\]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta k\text{W} = \Delta k\text{Wh}/\text{Hours} \times \text{CF}
\]

Where:

\[
\Delta k\text{Wh} = \text{calculated value above}
\]

\[
\text{Hours} = \text{Annual electric DHW recovery hours for showerhead use}
\]

\[
\text{Hours} = \left(\left(GPM\_base \times L\_base\right) \times \text{NSPD} \times 365.25\right) \times 0.773^{212} / \text{GPH}
\]

Where:

\[
\text{GPH} = \text{Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.}
\]

\[
\text{GPH} = 27.51
\]

\[
\text{CF} = \text{Coincidence Factor for electric load reduction}
\]

\[
\text{CF} = 0.0278^{213}
\]

---


212 77.3% is the proportion of hot 120F water mixed with 54.1°F supply water to give 105°F shower water.

213 Calculated as follows: Assume 11% showers take place during peak hours (based on: [http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282001%29-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf](http://www.aquacraft.com/sites/default/files/pub/DeOreo-%282001%29-Disaggregated-Hot-Water-Use-in-Single-Family-Homes-Using-Flow-Trace-Analysis.pdf)). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365.25 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for
EXAMPLE

For example, a direct-installed 1.5 GPM showerhead in an office with electric DHW where the number of showers is estimated at 3 per day:

\[
\Delta kW = (1308.4 / 674.1)\times 0.0278 \\
= 0.054 \text{ kW}
\]

FOSSIL FUEL IMPACT DESCRIPTIONS AND CALCULATION

\[
\Delta \text{Therms} = %\text{FossilDHW} \times ((\text{GPM}_\text{base} \times \text{L}_\text{base} - \text{GPM}_\text{low} \times \text{L}_\text{low}) \times \text{NSPD} \times 365.25) \times \text{EPG}_\text{gas} \times \text{ISR}
\]

Where:

\[
%\text{FossilDHW} = \text{proportion of water heating supplied by fossil fuel heating}
\]

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Fossil_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Fossil Fuel</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>84%²¹⁴</td>
</tr>
</tbody>
</table>

\[
\text{EPG}_\text{gas} = \text{Energy per gallon of Hot water supplied by gas} \\
= (8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_\text{gas} \times 100,000) \\
= 0.0063 \text{ Therm/gal}
\]

Where:

\[
\text{RE}_\text{gas} = \text{Recovery efficiency of gas water heater} \\
= 67\%²¹⁵ \\
100,000 = \text{Converts Btus to Therms (btu/Therm)}
\]

Other variables as defined above.

²¹⁴ Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

²¹⁵ 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%. Commercial properties are more similar to MF homes than SF homes. MF hot water is often provided by a larger commercial boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of .59 and the .75 for single family home. An average is used for this analysis by default.
EXAMPLE
For example, a direct-installed 1.5 GPM showerhead in an office with gas DHW where the number of showers is estimated at 3 per day:

$$\Delta \text{Therms} = 1.0 \times ((2.67 \times 8.2) - (1.5 \times 8.2)) \times 3 \times 365.25 \times 0.0063 \times 0.98$$

$$\Delta \text{Therms} = 64.9 \text{ therms}$$

WATER IMPACT DESCRIPTIONS AND CALCULATION

$$\Delta \text{gallons} = ((\text{GPM}_{\text{base}} \times \text{L}_{\text{base}} - \text{GPM}_{\text{low}} \times \text{L}_{\text{low}}) \times \text{NSPD} \times 365.25 \times \text{ISR}$$
Variables as defined above

EXAMPLE
For example, a direct-installed 1.5 GPM showerhead in an office where the number of showers is estimated at 3 per day:

$$\Delta \text{gallons} = ((2.67 \times 8.20) - (1.5 \times 8.20)) \times 3 \times 365.25 \times 0.98$$

$$\Delta \text{gallons} = 10,302 \text{ gallons}$$

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Reference</th>
</tr>
</thead>
</table>

MEASURE CODE: CI-HWE-LFSH-V04-180101

REVIEW DEADLINE: 1/1/2020
4.3.4 Commercial Pool Covers

DESCRIPTION

This measure refers to the installation of covers on commercial use pools that are heated with gas-fired equipment located either indoors or outdoors. By installing pool covers, the heating load on the pool boiler will be reduced by reducing the heat loss from the water to the environment and the amount of actual water lost due to evaporation (which then requires additional heated water to make up for it).

The main source of energy loss in pools is through evaporation. This is particularly true of outdoor pools where wind plays a larger role. The point of installing pool covers is threefold. First, it will reduce convective losses due to the wind by shielding the water surface. Second, it will insulate the water from the colder surrounding air. And third, it will reduce radiative losses to the night sky. In doing so, evaporative losses will also be minimized, and the boiler will not need to work as hard in replenishing the pool with hot water to keep the desired temperature.

This measure can be used for pools that (1) currently do not have pool covers, (2) have pool covers that are past the useful life of the existing cover, or (3) have pool covers that are past their warranty period and have failed.

DEFINITION OF EFFICIENT EQUIPMENT

For indoor pools, the efficient case is the installation of an indoor pool cover with a 5 year warranty on an indoor pool that operates all year.

For outdoor pools, the efficient case is the installation of an outdoor pool cover with a 5 year warranty on an outdoor pool that is open through the summer season.

DEFINITION OF BASELINE EQUIPMENT

For indoor pools, the base case is an uncovered indoor pool that operates all year.

For outdoor pools, the base case is an outdoor pool that is uncovered and is open through the summer season.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The useful life of this measure is assumed to be 6 years.\(^{216}\)

DEEMED MEASURE COST

The table below shows the costs for the various options and cover sizes. Since this measure covers a mix of various sizes, the average cost of these options is taken to be the incremental measure cost.\(^{217}\)

<table>
<thead>
<tr>
<th>Cover Size</th>
<th>Edge Style</th>
<th>Hemmed (indoor)</th>
<th>Weighted (outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-1,999 sq. ft.</td>
<td>$2.19</td>
<td>$2.24</td>
<td></td>
</tr>
<tr>
<td>2,000-2,999 sq. ft.</td>
<td>$2.01</td>
<td>$2.06</td>
<td></td>
</tr>
<tr>
<td>3,000+ sq. ft.</td>
<td>$1.80</td>
<td>$1.83</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>$2.00</td>
<td>$2.04</td>
<td></td>
</tr>
</tbody>
</table>

\(^{216}\) The effective useful life of a pool cover is typically one year longer than its warranty period. SolaPool Covers. Pool Covers Website, FAQ: "How long will my SolaPool cover blanket last?". Pool covers are typically offered with 3 and 5 year warranties with at least one company offering a 6 year warranty. Conversation with Trade Ally. Knorr Systems

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

NET TO GROSS RATIO

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS SAVINGS

The calculations are based on modeling runs using RSPEC! Energy Smart Pools Software that was created by the U.S. Department of Energy.\(^{218}\)

\[ \Delta \text{Therms} = \text{SavingFactor} \times \text{Size of Pool} \]

Where

Savings factor = dependant on pool location and listed in table below\(^{219}\)

<table>
<thead>
<tr>
<th>Location</th>
<th>Therm / sq-ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor</td>
<td>2.61</td>
</tr>
<tr>
<td>Outdoor</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Size of Pool = custom input

WATER IMPACT DESCRIPTIONS AND CALCULATION

\[ \Delta \text{Therms} = \text{WaterSavingFactor} \times \text{Size of Pool} \]

Where

WaterSavingFactor = Water savings for this measure dependant on pool location and listed in table below.\(^{220}\).

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual Savings Gal / sq-ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor</td>
<td>15.28</td>
</tr>
<tr>
<td>Outdoor</td>
<td>8.94</td>
</tr>
</tbody>
</table>

---

\(^{218}\) Full method and supporting information found in reference document: IL TRM - Business Pool Covers WorkPaper.docx. Note that the savings estimates are based upon Chicago weather data.

\(^{219}\) Business Pool Covers.xlsx

\(^{220}\) Ibid.
Size of Pool = Custom input

**DEEMED O&M COST ADJUSTMENT CALCULATION**

There are no O&M cost adjustments for this measure.

**MEASURE CODE: CI-HWE-PLCV-V01-130601**

**REVIEW DEADLINE: 1/1/2020**
4.3.5 Tankless Water Heater

**DESCRIPTION**

This measure covers the installation of on-demand or instantaneous tankless water heaters. Tankless water heaters function similar to standard hot water heaters except they do not have a storage tank. When there is a call for hot water, the water is heated instantaneously as it passes through the heating element and then proceeds to the user or appliance calling for hot water. Tankless water heaters achieve savings by eliminating the standby losses that occur in stand-alone or tank-type water heaters and by being more efficient than the baseline storage hot water heater.

This measure was developed to be applicable to the following program types: TOS, RF, ER.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

<table>
<thead>
<tr>
<th>Electric</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>To qualify for this measure, the tankless water heater shall be a new electric powered tankless hot water heater with an energy factor greater than or equal to 0.98 with an output greater than or equal to 5 GPM output at 70°F temperature rise.</td>
<td>To qualify for this measure, the tankless water heater shall meet or exceed the efficiency requirements for tankless hot water heaters mandated by the International Energy Conservation Code (IECC) 2012/2015, Table C404.2.</td>
</tr>
</tbody>
</table>

**DEFINITION OF BASELINE EQUIPMENT**

<table>
<thead>
<tr>
<th>Electric</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>The baseline condition is assumed to be an electric commercial-grade tanked water heater 50 or more gallon storage capacity with an energy factor less than or equal to 0.9 or the water heater is five or more years old.</td>
<td>The baseline condition is assumed to be a gas-fired tank-type water heater meeting the efficiency requirements mandated by the International Energy conservation Code (IECC) 2012/2015, Table C404.2</td>
</tr>
</tbody>
</table>

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

<table>
<thead>
<tr>
<th>Electric</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>The expected measure life is assumed to be 5 years.</td>
<td>The expected measure life is assumed to be 20 years.</td>
</tr>
</tbody>
</table>

**DEEMED MEASURE COST**

The incremental capital cost for an electric tankless heater this measure is assumed to be:

<table>
<thead>
<tr>
<th>Output (gpm) at delta T 70</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>$1050</td>
</tr>
<tr>
<td>10</td>
<td>$1050</td>
</tr>
<tr>
<td>15</td>
<td>$1950</td>
</tr>
</tbody>
</table>

The incremental capital cost for a gas fired tankless heater is as follows:

---


222 Ibid.

### DEEMED O&M COST ADJUSTMENTS

$100^{226}$

### LOADSHAPE

Loadshape C02 - Commercial Electric DHW

### COINCIDENCE FACTOR

The measure has deemed kW savings therefore a coincidence factor is not applied

### Algorithm

#### CALCULATION OF ENERGY SAVINGS

#### ELECTRIC ENERGY SAVINGS

The annual electric savings from an electric tankless heater is a deemed value and assumed to be:

<table>
<thead>
<tr>
<th>Output (gpm) at delta T 70</th>
<th>Savings (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>2,992</td>
</tr>
<tr>
<td>10.0</td>
<td>7,905</td>
</tr>
<tr>
<td>15.0</td>
<td>12,879</td>
</tr>
</tbody>
</table>

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

The annual kW savings from an electric tankless heater is a deemed value and assumed to be:

<table>
<thead>
<tr>
<th>Output (gpm) at delta T 70</th>
<th>Savings (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>0.34</td>
</tr>
<tr>
<td>10.0</td>
<td>0.90</td>
</tr>
<tr>
<td>15.0</td>
<td>1.47</td>
</tr>
</tbody>
</table>

---

224 Based on AOE historical average installation data of 42 tankless gas hot water heaters

225 [http://www.mncee.org/getattachment/7b8982e9-4d95-4bc9-8e64-f89033617f37/](http://www.mncee.org/getattachment/7b8982e9-4d95-4bc9-8e64-f89033617f37/), Low contractor estimate used to reflect less labor required in new construction of venting.

226 Water heaters (WH) require annual maintenance. There are different levels of effort for annual maintenance depending if the unit is gas or electric, tanked or tankless. Electric and gas tank water heater manufacturers recommend an annual tank drain to clear sediments. Also recommended are “periodic” inspections by qualified service professionals of operating controls, heating element and wiring for electric WHs and thermostat, burner, relief valve internal flue-way and venting systems for gas WHs. Tankless WH require annual maintenance by licensed professionals to clean control compartments, burners, venting system and heat exchangers. This information is from WH manufacturer product brochures including GE, Rennai, Rheem, Takagi and Kenmore. References for incremental O&M costs were not found. Therefore the incremental cost of the additional annual maintenance for tankless WH is estimated at $100.


228 Ibid.
### Natural Gas Savings

\[
\Delta \text{Therms} = \left[ \left( \text{Wgal} \times 8.33 \times 1 \times (\text{Tout} - \text{Tin}) \times \left[ \frac{1}{\text{Eff base}} \right] - \left( \frac{1}{\text{Eff ee}} \right) \right] \right] / 100,000 + \left[ \left( \frac{\text{SL} \times 8,766}{\text{Eff base}} \right) \right] / 100,000 \text{ Btu/Therms}
\]

Where:

- **Wgal**: Annual water use for equipment in gallons
  - custom, otherwise assume 21,915 gallons

- **8.33 lbm/gal**: weight in pounds of one gallon of water

- **1 Btu/lbm°F**: Specific heat of water: 1 Btu/lbm/°F

- **8,766 hr/yr**: hours a year

- **Tout**: Unmixed Outlet Water Temperature
  - custom, otherwise assume 130 °F

- **Tin**: Inlet Water Temperature
  - custom, otherwise assume 54.1 °F

- **Eff base**: Rated efficiency of baseline water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et); see table below

<table>
<thead>
<tr>
<th>Input Btu/hr of existing, tanked water heater</th>
<th>Eff base</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size: ≤ 75,000 Btu/hr</td>
<td>0.67 - 0.0019*Tank Volume</td>
<td>Energy Factor</td>
</tr>
<tr>
<td>Size: &gt;75,000 Btu/hr and ≤ 155,000 Btu/hr</td>
<td>80%</td>
<td>Thermal Efficiency</td>
</tr>
<tr>
<td>Size: &gt;155,000 Btu/hr</td>
<td>80%</td>
<td>Thermal Efficiency</td>
</tr>
</tbody>
</table>

Where:

- Tank Volume = custom input, if unknown assume 60 gallons for Size: ≤ 75,000 Btu/hr

Please note: Units in base case must match units in efficient case. If Energy Factor used in base case, Energy Factor to be used in efficient case. If Thermal Efficiency is used in base case, Thermal Efficiency must be used in efficient case.

- **Eff ee**: Rated efficiency of efficient water heater expressed as Energy Factor (EF) or Thermal Efficiency (Et)
  - custom input, if unknown assume 0.84

---

229 21,915 gallons is an estimate of 60 gal/day for 365.25 days/yr. If building type is known, reference 2007 ASHRAE Handbook HVAC Applications p. 49.14 Table 7 Hot Water Demands and Use for Various Types of Buildings to help estimate hot water consumption.


231 August 31, 2011 Memo of Savings for Hot Water Savings Measures to Nicor Gas from Navigant states that 54.1°F was calculated from the weighted average of monthly water mains temperatures reported in the 2010 Building America Benchmark Study for Chicago-Waukegan, Illinois.


233 Specifications of energy efficient tankless water heater. Reference Consortium for Energy Efficiency (CEE) which maintains a list of high efficiency tankless water heaters which currently have Energy Factors up to .96. Ameren currently requires minimum .82 energy factor.
SL = Stand-by Loss in Base Case Btu/hr

SL = custom input based on formula in table below, if unknown assume unit size in table below

<table>
<thead>
<tr>
<th>Input Btu/h of new, tankless water heater</th>
<th>Standby Loss (SL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size: ≤ 75,000 Btu/hr</td>
<td>0</td>
</tr>
<tr>
<td>Size: &gt;75,000 Btu/hr</td>
<td>(Input rating/800)+(110*√Tank Volume)</td>
</tr>
</tbody>
</table>

Where:

Tank Volume = custom input, if unknown assume, 60 gallons for <75,000 Btu/hr, 75 gallons for >75,000 Btu/hr and ≤ 155,000 Btu/hr and 150 for Size >155,000 Btu/hr

Input Rating = nameplate Btu/hr rating of water heater

**EXAMPLE**

For example, a 75,000 Btu/hr tankless unit using 21,915 gal/yr with outlet temperature at 130.0 and inlet temperature at 54.1, replacing a baseline unit with 0.8 thermal efficiency and standby losses of 1008.3 btu/hr:

\[
\Delta \text{Therms} = \left[ \frac{[21,915 \times 8.33 \times 1 \times (130 - 54.1) \times \left[\frac{1}{0.8} - \frac{1}{0.84}\right]/100,000]}{100,000} \right] + \left[ \frac{1008.3 \times 8,766}{0.8} \right] / 100,000
\]

\[= 115 \text{ Therms}\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The deemed O&M cost adjustment for a gas fired tankless heater is $100

**REFERENCE TABLES**

Minimum Performance Water Heating Equipment

---

234 Stand-by loss is provided in 2012/2015 IECC, Table C404.2, Minimum Performance of Water-Heating Equipment

### Table C404.2: Minimum Performance of Water-Heating Equipment

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category (Input)</th>
<th>Subcategory or Rating Condition</th>
<th>Performance Requireda</th>
<th>Test Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water heaters, electric</td>
<td>≤ 12 kW</td>
<td>Resistance</td>
<td>0.97 - 0.00 112 V, EF</td>
<td>DOE 10 CFR Part 410</td>
</tr>
<tr>
<td></td>
<td>&gt; 12 kW</td>
<td>Resistance</td>
<td>1.7314 - 165 SL, Btu/h</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td></td>
<td>≤ 24 Amps and ≤ 260 volts</td>
<td>Heat pump</td>
<td>0.93 - 0.00 112 V, EF</td>
<td>DOE 10 CFR Part 410</td>
</tr>
<tr>
<td>Storagewater heaters, gas</td>
<td>≤ 75,000 Btu/h</td>
<td>≥ 20 gal</td>
<td>0.37 - 0.0019 V, EF</td>
<td>DOE 10 CFR Part 410</td>
</tr>
<tr>
<td></td>
<td>&gt; 75,000 Btu/h and ≤ 155,000 Btu/h</td>
<td>&lt; 4,000 Btu/h/gal</td>
<td>80% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td></td>
<td>&gt; 155,000 Btu/h</td>
<td>&lt; 4,000 Btu/h/gal</td>
<td>80% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Instantaneous water heaters, gas</td>
<td>&gt; 60,000 Btu/h and &lt; 200,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 2 gal</td>
<td>0.82 - 0.00 119 V, EF</td>
<td>DOE 10 CFR Part 410</td>
</tr>
<tr>
<td></td>
<td>≥ 200,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 10 gal</td>
<td>80% E_e</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td></td>
<td>≥ 200,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 10 gal</td>
<td>80% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Storagewater heaters, oil</td>
<td>≤ 106,000 Btu/h</td>
<td>≥ 20 gal</td>
<td>0.59 - 0.0019 V, EF</td>
<td>DOE 10 CFR Part 410</td>
</tr>
<tr>
<td></td>
<td>≥ 106,000 Btu/h</td>
<td>&lt; 4,000 Btu/h/gal</td>
<td>78% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Instantaneous water heaters, oil</td>
<td>≤ 210,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and &lt; 2 gal</td>
<td>0.39 - 0.0019 V, EF</td>
<td>DOE 10 CFR Part 410</td>
</tr>
<tr>
<td></td>
<td>&gt; 210,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and &lt; 10 gal</td>
<td>80% E_e</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td></td>
<td>&gt; 210,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 10 gal</td>
<td>78% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Hot water supply boilers, gas and oil</td>
<td>≥ 300,000 Btu/h and ≤ 12,500,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 10 gal</td>
<td>80% E_e</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Hot water supply boilers, gas</td>
<td>≥ 300,000 Btu/h and &lt; 12,500,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 10 gal</td>
<td>80% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Hot water supply boilers, oil</td>
<td>≥ 300,000 Btu/h and &lt; 12,500,000 Btu/h</td>
<td>≥ 4,000 Btu/h/gal and ≥ 10 gal</td>
<td>78% E_e (Q_8000 + 110,000 SL, Btu/h)</td>
<td>ANSI Z211.0.3</td>
</tr>
<tr>
<td>Pool heaters, gas and oil</td>
<td>All</td>
<td>—</td>
<td>78% E_e</td>
<td>ASHRAE 145</td>
</tr>
<tr>
<td>Heat pump pool heaters</td>
<td>All</td>
<td>—</td>
<td>4.0 COP</td>
<td>ASHRAE 1160</td>
</tr>
<tr>
<td>Unified storage tanks</td>
<td>All</td>
<td>—</td>
<td>Minimum insulation requirement R-12.5 (h·ft²·°F)/Btu</td>
<td>(none)</td>
</tr>
</tbody>
</table>

For SI: °C = (°F) - 32/1.8, 1 Btu = 1.055 L, 1 British thermal unit per hour = 0.2931 W, 1 gallon = 3.785 L, 1 British thermal unit per hour per gallon = 0.001 W/L.

a. Energy factor (EF) and thermal efficiency (E_e) are minimum requirements. In the EF equation, E is the rated volume in gallons.

b. Standby loss (SL) is the maximum Btu/h based on a normal 70°F temperature difference between stored water and ambient requirement. In the SL equation, Q is the nameplate input rate in Btu/h. In the SL equation for electric water heaters, E is the rated volume in gallons In the SL equation for oil and gas water heaters, E is the rated volume in gallons.

c. Instantaneous water heaters with input rate below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.
MEASURE CODE: CI-HWE-TKWH-V03-160601

REVIEW DEADLINE: 1/1/2019
4.3.6 Ozone Laundry

**DESCRIPTION**

A new ozone laundry system(s) is added-on to new or existing commercial washing machine(s) using hot water heated with natural gas. The system generates ozone (O\textsubscript{3}), a naturally occurring molecule, which helps clean fabrics by chemically reacting with soils in cold water. Adding an ozone laundry system(s) will reduce the amount of chemicals, detergents, and hot water needed to wash linens. Using ozone also reduces the total amount of water consumed, saving even more in energy.

Natural gas energy savings will be achieved at the hot water heater/boiler as they will be required to produce less hot water to wash each load of laundry. The decrease in hot water usage will increase cold water usage, but overall water usage at the facility will decrease.

Electric savings can be realized through reduced washer cycle length and reduced pumping load at the boiler feeding the commercial washers. The increased usage associated with operating the ozone system should also be accounted for when determining total kWh impact. Data reviewed for this measure characterization indicated that pumping savings should be accounted for, but washer savings and ozone generator consumption are comparatively so small that they can be ignored.

The reduced washer cycle length may decrease the dampness of the clothes when they move to the dryer. This can result in shorter runtimes which result in gas and electrical savings. However, at this time, there is inconclusive evidence that energy savings are achieved from reduced dryer runtimes so the resulting dryer effects are not included in this analysis. Additionally, there would be challenges verifying that dryer savings will be achieved throughout the life of the equipment.

This incentive only applies to the following facilities with on-premise laundry operations:

- Hotels/motels
- Fitness and recreational sports centers.
- Healthcare (excluding hospitals)
- Assisted living facilities

Ozone laundry system(s) could create significant energy savings opportunities at other larger facility types with on-premise laundry operations (such as correctional facilities, universities, and staff laundries), however, the results included in this analysis are based heavily on past project data for the applicable facility types listed above and may not apply to facilities outside of this list due to variances in number of loads and average pound (lbs.)-capacity per project site. Projects at these facilities should continue to be evaluated through custom programs and the applicable facility types and the resulting analysis should be updated based on new information.

This measure was developed to be applicable to the following program types: TOS, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

A new ozone laundry system(s) is added-on to new or existing commercial washing machine(s) using hot water heated with natural gas. The ozone laundry system(s) must transfer ozone into the water through:

- Venturi Injection
- Bubble Diffusion
- Additional applications may be considered upon program review and approval on a case by case basis
DEFINITION OF BASELINE EQUIPMENT

The base case equipment is a conventional washing machine system with no ozone generator installed. The washing machines are provided hot water from a gas-fired boiler.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure equipment effective useful life (EUL) is estimated at 10 years based on typical lifetime of the ozone generator’s corona discharge unit.\textsuperscript{236}

DEEMED MEASURE COST

The actual measure costs should be used if available. If not a deemed value of $79.84 / lbs capacity should be used\textsuperscript{237}.

LOADSHAPE

Loadshape C53 – Flat

COINCIDENCE FACTOR

Past project documentation and data collection is not sufficient to determine a coincidence factor for this measure. Value should continue to be studied and monitored through additional studies due to limited data points used for this determination

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings can be realized through reduced washer cycle length and reduced pumping load at the boiler feeding the commercial washers. There is also an increased usage associated with operating the ozone system. Data reviewed for this measure characterization indicated that while pumping savings is significant and should be accounted for, washer savings and ozone generator consumption are negligible, counter each other out and are well within the margin of error so these are not included to simplify the characterization\textsuperscript{238}.

\[ \Delta \text{kWh}_{\text{PUMP}} = \text{HP} \times \text{HP}_{\text{CONVERSION}} \times \text{Hours} \times \%\text{water_savings} \]

Where:

\[ \Delta \text{kWh}_{\text{PUMP}} = \text{Electric savings from reduced pumping load} \]

\[ \text{HP} = \text{Brake horsepower of boiler feed water pump;} \]

\[ = \text{Actual or use 5 HP if unknown}\textsuperscript{239} \]

\textsuperscript{236} Aligned with other national energy efficiency programs and confirmed with national vendors

\textsuperscript{237} Average costs per unit of capacity were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR), as well as from the Nicor Custom Incentive Program, and the Nicor Emerging Technology Program (ETP). See referenced document Table 2 and RSMeans Mechanical Cost Data, 31st Annual Edition (2008)

\textsuperscript{238} Washer savings were reviewed but were considered negligible and not included in the algorithm (0.00082 kWh / lbs-capacity, determined through site analysis through Nicor Emerging Technology Program (ETP) and confirmed with national vendors). Note that washer savings from Nicor’s site analysis are smaller than those reported in a WI Focus on Energy case study (0.23kWh/100lbs, Hampton Inn Brookfield, November 2010). Electric impact of operating ozone generator (0.0021 kWh / lbs-capacity same source as washer savings) was also considered negligible and not included in calculations. Values should continue to be studied and monitored through additional studies due to limited data points used for this determination.

\textsuperscript{239} Assumed average horsepower for boilers connected to applicable washer
HP CONVERSION = Conversion from Horsepower to Kilowatt
                   = 0.746

Hours = Actual associated boiler feed water pump hours
       = 800 hours if unknown

%water_savings = water reduction factor: how much more efficient an ozone injection washing machine is compared to a typical conventional washing machine as a rate of hot and cold water reduction.
                   = 25%\(^{241}\)

Using defaults above:
\[
\Delta kWh_{PUMP} = 5 \times 0.746 \times 800 \times 0.25
\]
\[
= 746 \text{ kWh}
\]

Default per lb capacity: \(\Delta kWh_{PUMP} / \text{lb capacity}\)

Where:

Lbs-Capacity = Average Capacity in lbs of washer
              = 254.38\(^{242}\)

\[
\Delta kWh_{PUMP} / \text{lb capacity} = 746 / 254.38
\]
\[
= 2.93 \text{ kWh/lb-capacity}
\]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Past project documentation and data collection is not sufficient to determine summer coincident peak demand savings for this measure. Value should continue to be studied and monitored through additional studies due to limited data points used for this determination. In absence of site-specific data, the summer coincident peak demand savings should be assumed to be zero.

\(\Delta kW = 0\)

NATURAL GAS SAVINGS

\[\Delta \text{Therm} = \text{Therm}_{\text{Baseline}} \times \%\text{hot\_water\_savings}\]

Where:

\(\Delta \text{Therm}\) = Gas savings resulting from a reduction in hot water use, in therm.

\(\text{Therm}_{\text{Baseline}}\) = Annual Baseline Gas Consumption

\(^{240}\) Engineered estimate provided by CLEAResult review of Nicor custom projects. Machines spent approximately 7 minutes per hour filling with water and were in operation approximately 20 hours per day. Total pump time therefore estimated as 7/60 * 20 * 365 = 852 hours, and rounded down conservatively to 800 hours.

\(^{241}\) Average water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 6 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

\(^{242}\) Average lbs-capacity per project site was generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR), as well as from the Nicor Custom Incentive Program, and the Nicor Emerging Technology Program (ETP). See referenced document Table 2.
\[ WHE = \text{water heating energy: energy required to heat the hot water used} \]
\[ WUtiliz = \text{washer utilization factor: the annual pounds of clothes washed per year} \]
\[ WUsage_{\text{hot}} = \text{hot water usage factor: how much hot water a typical conventional washing machine utilizes, normalized per pounds of clothes washed} \]

Where:

\[ WHE = 0.00885 \text{ therms/gallon} \]

\[ WUtiliz = \text{actual, if unknown use 916,150 lbs laundry, approximately equivalent to 13 cycles/day} \]

\[ WUsage_{\text{hot}} = 1.19 \text{ gallons/lbs laundry} \]

Using defaults above:

\[ \text{Therm}_{\text{Baseline}} = 0.00885 \times 916,150 \times 1.19 = 9,648 \text{ therms} \]

Default per lb capacity:

\[ \text{Therm}_{\text{Baseline}} \text{ / lb capacity} = 9,648 / 254.38 = 37.9 \text{ therms / lb-capacity} \]

\[ \%_{\text{hot water savings}} = \text{hot water reduction factor: how much more efficient an ozone injection washing machine is, compared to a typical conventional washing machine, as a rate of hot water reduction} \]

\[ \%_{\text{hot water savings}} = 81\% \]

Savings using defaults above:

\[ \Delta_{\text{Therm}} = \text{Therm}_{\text{Baseline}} \times \%_{\text{hot water savings}} \]

\[ = 9648 \times 0.81 = 7,815 \text{ therms} \]

Default per lb capacity:

\[ \Delta_{\text{Therm}} \text{ / lb-capacity} = 7815 / 254.38 = 30.7 \text{ therms / lb-capacity} \]

---

243 Assuming boiler efficiency is the regulated minimum efficiency (80%), per Title 20 Appliance Standard of the California Energy Regulations (October 2007). The incoming municipal water temperature is assumed to be 55 °F with an average hot water supply temperature of 140°F, based on default test procedures on clothes washers set by the Department of Energy’s Office of Energy Efficiency and Renewable Energy (Federal Register, Vol. 52, No. 166). Enthalpies for these temperatures (107 btu/lbs at 140F, 23.07 btu/lbs at 55F) were obtained from ASHRAE Fundamentals.

244 Average utilization factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. Table 3 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects.

245 Average hot water usage factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. 

246 Average hot water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 5 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations.
WATER IMPACT DESCRIPTIONS AND CALCULATION

The water savings calculations listed here account for the combination of hot and cold water used. Savings calculations for this measure were based on the reduction in total water use from implementing an ozone washing system to the base case. There are three main components in obtaining this value:

\[ \Delta \text{gallons} = W\text{Usage} \times W\text{Utiliz} \times \%\text{water_savings} \]

Where:

\( \Delta \text{gallons} \) = reduction in total water use from implementing an ozone washing system to the base case

\( W\text{Usage} \) = water usage factor: how efficiently a typical conventional washing machine utilized hot and cold water normalized per unit of clothes washed

\( W\text{Utiliz} \) = washer utilization factor: the annual pounds of clothes washed per year

\( \%\text{water_savings} \) = water reduction factor: how much more efficient an ozone injection washing machine is compared to a typical conventional washing machine as a rate of hot and cold water reduction.

Savings using defaults above:

\[ \Delta \text{Gallons} = W\text{Usage} \times W\text{Utiliz} \times \%\text{water_savings} \]

\[ = 2.03 \times 916,150 \times 0.25 \]

\[ = 464,946 \text{ gallons} \]

Default per lb capacity:

\[ \Delta \text{Gallons} / \text{lb-capacity} = 464,946 / 254.38 \]

\[ = 1,828 \text{ gallons / lb-capacity} \]

DEEMED O&M COST ADJUSTMENT CALCULATION

Maintenance is required for the following components annually:\(^{250}\)

- Ozone Generator: filter replacement, check valve replacement, fuse replacement, reaction chamber inspection/cleaning, reaction chamber o-ring replacement
- Air Preparation – Heat Regenerative: replacement of two medias
- Air Preparation – Oxygen Concentrators: filter replacement, pressure relief valve replacement, compressor rebuild
- Venturi injector: check valve replacement

---

\(^{247}\) Average water usage factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. summarizes data gathered from several NRR-DR projects

\(^{248}\) Average utilization factors were generated using data collected from existing ozone laundry projects that received incentives under the NRR-DR program. Table 3 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects

\(^{249}\) Average water reduction factors were generated using data collected from existing ozone laundry projects that received incentives under the Non-Residential Retrofit Demand Reduction program (NRR-DR). Table 6 summarizes data gathered from several NRR-DR projects, Nicor Custom projects, and Nicor ETP projects. Nicor Savings Numbers are associated with ACEE_AWE_Ozone Laundry / From Gas Savings Calculations

\(^{250}\) Confirmed through communications with national vendors and available references E.g. http://ozonelaundry.wordpress.com/2010/11/17/the-importance-of-maintenance/
Maintenance is expected to cost $0.79 / lbs capacity.

REFERENCES

2. "Health, United States, 2008" Table 120, U.S. Department of Health & Human Services, Centers for Disease Control & Prevention, National Center for Health Statistics, http://www.cdc.gov/nchs/data/hus/hus08.pdf#120
7. Federal Register, Vol. 52, No. 166
8. 2009 ASHRAE Handbook – Fundamentals, Thermodynamic Properties of Water at Saturation, Section 1.1 (Table 3), 2009
9. Table 2 through 6: Excel file summarizing data collected from existing ozone laundry projects that received incentives under the NRR-DR program

MEASURE CODE CI-HWE-OZLD-VO1-140601

REVIEW DEADLINE: 1/1/2020
4.3.7 Multifamily Central Domestic Hot Water Plants

**DESCRIPTION**

This measure covers multifamily central domestic hot water (DHW) plants with thermal efficiencies greater than or equal to 88%. This measure is applicable to any combination of boilers and storage tanks provided the thermal efficiency of the boilers is greater than 88%. Plants providing other than solely DHW are not applicable to this measure.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify the boiler(s) must have a Thermal Efficiency of 88% or greater and supply domestic hot water to multifamily buildings.

**DEFINITION OF BASELINE EQUIPMENT**

For TOS the baseline boiler is assumed to have a Thermal Efficiency of 80%.\(^{251}\)

For Early Replacement the savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit as above and efficient unit consumption for the remainder of the measure life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the domestic hot water boilers is 15 years.\(^{252}\)

**DEEMED MEASURE COST**

TOS: The actual install cost should be used for the efficient case, minus the baseline cost assumption provided below:

<table>
<thead>
<tr>
<th>Capacity Range</th>
<th>Baseline Installed Cost (^{253}) per kBtuH</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;300 kBtuH</td>
<td>$65 per kBTUH</td>
</tr>
<tr>
<td>300 – 2500 kBtuH</td>
<td>$38 per kBTUH</td>
</tr>
<tr>
<td>&gt;2500 kBtuH</td>
<td>$32 per kBTUH</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

---

\(^{251}\) International Energy Conservation Code (IECC) 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment


\(^{253}\) Baseline install costs are based on data from the W017 Itron California Measure Cost Study, accessed via [http://www.energydataweb.com/cpuc/search.aspx](http://www.energydataweb.com/cpuc/search.aspx). The data is provided in a file named “MCS Results Matrix – Volume I”.
CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

There are no anticipated electrical savings from this measure.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

Time of Sale:

\[ \Delta \text{Therms} = \text{Hot Water Savings} + \text{Standby Loss Savings} \]

\[ \Delta \text{Therms} = \left[ \left( \text{MFHH} \times \text{#Units} \times \text{GPD} \times \text{Days/yr} \times \text{Water} \times (\text{Tout} - \text{Tin}) \times (1/\text{Eff}_b - 1/\text{Eff}_e) \right) / 100,000 \right] + \left[ \left( \text{SL} \times \text{Hours/yr} \times (1/\text{Eff}_b - 1/\text{Eff}_e) \right) / 100,000 \right] \]

Early Replacement:\n
\[ \Delta \text{Therms for remaining life of existing unit (1st 5 years)}: \]

\[ \Delta \text{Therms} = \left[ \left( \text{MFHH} \times \text{#Units} \times \text{GPD} \times \text{Days/yr} \times \text{Water} \times (\text{Tout} - \text{Tin}) \times (1/\text{Eff}_e) \right) / 100,000 \right] + \left[ \left( \text{SL} \times \text{Hours/yr} \times (1/\text{Eff}_e) \right) / 100,000 \right] \]

\[ \Delta \text{Therms for remaining measure life (next 10 years)}: \]

\[ \Delta \text{Therms} = \left[ \left( \text{MFHH} \times \text{#Units} \times \text{GPD} \times \text{Days/yr} \times \text{Water} \times (\text{Tout} - \text{Tin}) \times (1/\text{Eff}_b - 1/\text{Eff}_e) \right) / 100,000 \right] + \left[ \left( \text{SL} \times \text{Hours/yr} \times (1/\text{Eff}_b - 1/\text{Eff}_e) \right) / 100,000 \right] \]

Where:

- MFHH = number of people in Multi-Family House Hold
  - Actual. If unknown assume 2.1 persons/unit\(^{255}\)
- #Units = Number of units served by hot water boiler
  - Actual
- GPD = Gallons of hot water used per person per day
  - Actual. If unknown assume 17.6 gallons per person per day\(^{256}\)
- Days/yr = 365.25
- Water = Specific Weight of Water
  - 8.33 gal/lb
- Tout = tank temperature of hot water
  - 125°F or custom
- Tin = Incoming water temperature from well or municipale system

\(^{254}\) 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).


Eff_base = thermal efficiency of base unit 
= 80%\(^{258}\)

Eff_ee = thermal efficiency of efficient unit complying with this measure 
= Actual. If unknown assume 88%\(^{258}\)

Eff_exist = thermal efficiency of existing unit 
= Actual. If unknown assume 73%\(^{259}\)

SL = Standby Loss\(^{260}\) 
= (Input rating / 800) + (110 * \(\sqrt{\text{Tank Volume}}\))

Input rating = Name plate input capacity in Btuh
Tank Volume = Rated volume of the tank in gallons

Hours / yr = 8766 hours
100,000 = btu/therm


\(^{258}\) IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment

\(^{259}\) Based upon DCEO data provided 10/2014; average age adjusted efficiency of existing units replaced through the program. Efficiency age adjustment of 0.5% per year based upon NREL “Building America Performance Analysis Procedures for Existing Homes”.

\(^{260}\) Stand-by loss is provided in IECC 2012/2015, Table C404.2, Minimum Performance of Water-Heating Equipment
EXAMPLES

Time of Sale:
For example, an 88% 1000 gallon boiler with 150,000 Btuh input rating installed serving 50 units.

\[
\Delta \text{Therms} = \text{Hot Water Savings} + \text{Standby Loss Savings} \\
= [(\text{MFHH} \times \#\text{Units} \times \text{GPD} \times \text{Days/yr} \times \nu\text{Water} \times (\text{Tout} - \text{Tin}) \times (1/\text{Eff}_{\text{base}} - 1/\text{Eff}_{\text{ee}})) / 100,000] + [(\text{SL} \times \text{Hours/yr} \times (1/\text{Eff}_{\text{base}} - 1/\text{Eff}_{\text{ee}})) / 100,000] \\
= [(2.1 \times 50 \times 17.6 \times 8.33 \times 365.25 \times 1.0 \times (125-54) \times (1/0.8 - 1/0.88)) / 100000] + \\
[(150000/800 + (110 \times \sqrt{1000})) \times 8766 \times (1/0.8 - 1/0.88)) / 100000] \\
= 454 + 37 \\
= 490 \text{ therms}
\]

Early Replacement:
For example, an 88% 1000 gallon boiler with 150,000 Btuh input rating installed serving 50 units replaces a working unit with unknown efficiency.

\[
\Delta \text{Therms for remaining life of existing unit (1st 5 years)}: \\
= [(2.1 \times 50 \times 17.6 \times 8.33 \times 365.25 \times 1.0 \times (125-54) \times (1/0.73 - 1/0.88)) / 100000] + \\
[((150000/800 + (110 \times \sqrt{1000})) \times 8766 \times (1/0.73 - 1/0.88)) / 100000] \\
= 932 + 75 \\
= 1007 \text{ therms}
\]

\[
\Delta \text{Therms for remaining measure life (next 10 years)}: \\
= 454 + 37 \text{ (as above)} \\
= 490 \text{ therms}
\]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HWE-MDHW-V02-160601

REVIEW DEADLINE: 1/1/2023
4.3.8 Controls for Central Domestic Hot Water

**DESCRIPTION**

Demand control recirculation pumps seek to reduce inefficiency by combining control via temperature and demand inputs, whereby the controller will not activate the recirculation pump unless both (a) the recirculation loop return water has dropped below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

Re-circulating pump shall cycle on based on (a) the recirculation loop return water dropping below a prescribed temperature (e.g. 100°F) and (b) a CDHW demand is sensed as water flow through the CDHW system.

**DEFINITION OF BASELINE EQUIPMENT**

The base case for this measure category are existing, un-controlled Recirculation Pumps on gas-fired Central Domestic Hot Water Systems.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The effective useful life is 15 years\(^2^{61}\).

**DEEMED MEASURE COST**

The average cost of the demand controller circulation kit is $1,608 with an installation cost of $400 for a total measure cost of $2,008\(^2^{62}\).

**LOADSHAPE**

Loadshape C02 - Non-Residential Electric DHW

**COINCIDENCE FACTOR**

N/A

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Deemed at 656 kWh\(^2^{63}\).

---


\(^{262}\) The incremental costs were averaged based on the following multi-family and dormitory building studies:

- Studies performed in multiple dormitory buildings in the California region for Southern California Gas’ PREPS Program, 2012.

\(^{263}\) This value is the average kWh saved per pump based on results from Multi-Family buildings studied in Nicor Gas Emerging Technology Program study and Southern California Gas’ study in multiple dormitory buildings. Note this value does not reflect
Savings from electric units but electrical savings from gas-fired units. See ‘CDHW Controls Summary Calculations.xlsx’ for more information.

264 See ‘CDHW Controls Summary Calculations.xlsx’ for more information.

265 This is an average number based on Residential Energy Consumption Survey (2009) data and Commercial Building Energy Consumption Survey (2012) data compiled by U.S. Energy Information Administration, for buildings with more than 5 apartments in Illinois and Nursing Home and Assisted Living facilities in Midwest.

266 This is based on Commercial Building Energy Consumption Survey (2012) data compiled by U.S. Energy Information Administration, for Education facilities in East North Central.

267 This is based on studies done in multiple university dormitory buildings in the California region, for Southern California Gas’ PREPS Program, 2012. It closely matches the design guidelines outlined in 2007 ASHRAE Handbook, Chapter 49: Service Water Heating, Table 7, and assumes 1 to 2 students per dorm room based on typical dorm room layouts. This source provides the source for dormitory assumptions of Boiler Input Capacity, t_{low occ}, R_{normal occ} and R_{low occ}.

268 This is based on studies done at Multi-Family Buildings for the Nicor Gas Emerging Technology Program by Gas Technology Institute. It closely matches the design guidelines outlined in 2007 ASHRAE Handbook, Chapter 49: Service Water Heating, Table 9, and assumes 2.1 persons per apartment as per ComEd PY3 Multi-Family Home Energy Savings Program Evaluation Report Final, May 16, 2012 by Navigant. This source provides the source for dormitory assumptions of Boiler Input Capacity, t_{low occ}, R_{normal occ} and R_{low occ}.

269 Based on results of studies performed in multiple university dormitory buildings in the California region, for Southern California Gas’ PREPS Program, 2012.

270 Based on results of the studies done at Multi-Family Buildings for the Nicor Gas Emerging Technology Program:


271 Low occupancy periods for dormitory buildings can be assumed as vacation day or holiday occupancy.
\( R_{\text{normal occ}} \) = Reduction(\%) in total operating hours of domestic hot water burner, due to installed central domestic hot water controls, during normal occupancy period.

= 22.44\% for Dormitories
= 24.02\% for Multi-Family Buildings

\( R_{\text{low occ}} \) = Reduction(\%) in total operating hours of domestic hot water burner, due to installed central domestic hot water controls, during low occupancy period.

= 44.57\% for Dormitories
= 0\% for Multi-Family Buildings

Based on defaults above:

\[ \Delta \text{Therms} = 30.1 \times \text{number of rooms (for Dormitories)} \]
\[ = 62.7 \times \text{number of apartments (for Multi-Family buildings)} \]

\begin{center}
\begin{tabular}{|p{0.9\textwidth}|}
\hline
\textbf{EXAMPLE} \\
\hline
For example, a dormitory building has a 400,000 BTU/hr boiler whose burner operates for an estimated 580 hours during vacation months and 1,300 hours during regular occupancy months. Savings from installing central domestic hot water controls in this building are - \\
\[ \Delta \text{Therms} = 400,000 \times (1,300 \times 0.2244 + 580 \times 0.4457) / 100,000 \]
\[ = 2,200.9 \text{ therms} \]
\hline
\end{tabular}
\end{center}

\begin{center}
\textbf{WATER IMPACT DESCRIPTIONS AND CALCULATION} \\
N/A
\end{center}

\begin{center}
\textbf{DEEMED O&M COST ADJUSTMENT CALCULATION} \\
N/A
\end{center}

\begin{center}
\textbf{MEASURE CODE: CI-HWE-CDHW-V02-180101} \\
\end{center}

\begin{center}
\textbf{REVIEW DEADLINE: 1/1/2022} \\
\end{center}
4.3.9 Heat Recovery Grease Trap Filter

DESCRIPTION
A heat recovery grease trap filter combines grease filters and a heat exchanger to recover heat leaving kitchen hoods. As a direct replacement for conventional hood mounted filters in commercial kitchens, they are plumbed to the domestic hot water system to provide preheating energy to incoming water.

This measure was developed to be applicable to the following program types: TOS and RF. If applied to other program types, the measure savings should be verified. For NC projects, this measure may be applicable if code requirements are otherwise satisfied.

DEFINITION OF EFFICIENT EQUIPMENT
Grease filters with heat exchangers carrying domestic hot water in kitchen exhaust air ducts.

DEFINITION OF BASELINE EQUIPMENT
Kitchen exhaust air duct with constant air flow\(^{272}\) and no heat recovery.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
THE EXPECTED MEASURE LIFE IS ASSUMED TO BE 15 YEARS.\(^{273}\)

DEEMED MEASURE COST
FULL INSTALLATION COSTS, INCLUDING PLUMBING MATERIALS, LABOR AND ANY ASSOCIATED CONTROLS, SHOULD BE USED FOR SCREENING PURPOSES.

LOADSHAPE
Loadshape C01 - Commercial Electric Cooking

COINCIDENCE FACTOR
Summer Peak Coincidence Factor for measure is provided below for different building type\(^{274}\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Algorithm

\(^{272}\) Savings methodology factors are for a constant speed fan.

\(^{273}\) Professional judgement, consistent with expected lifetime of kitchen demand ventilation controls and other kitchen equipment.

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For electric hot water heaters:

\[ \Delta k\text{Wh} = \frac{[(\text{Meal/Day} \times \text{HW/Meal} \times \text{Days/Year}) \times \text{lbs/gal} \times \text{BTU/lb.}^\circ\text{F} \times (\Delta T/\text{filter} \times \text{Qty_Filter}) \times 0.00293]}{\eta_{\text{HeaterElec}}} \]

Where:

- Meal/Day = Average number of meals served per day. If not directly available, see Table 1.
- HW/Meal = Hot water required per meal
  - = 3 gal/meal\(^{275}\)
- Days/Year = Number of days kitchen operates per year. If not directly available, see Table 1.
- Lbs/gal = Weight of water
  - = 8.3 lbs/gal
- BTU/lb.\(^\circ\text{F}\) = Specific heat of water
  - = 1.0
- \(\Delta T/\text{filter}\) = Temperature difference of domestic water across each filter
  - = 5.8\(^\circ\text{F}]/\text{filter}\(^{276}\)
- Qty_Filter = Number of heat recovery grease trap filters installed. If not directly available, see Table 1.

\(\eta_{\text{HeaterElec}}\) = Efficiency of the Electric water heater.

\(\Delta T/\text{filter}\) = Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates.

### Commercial Kitchen Load based on Building Type

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Meals/Day</th>
<th>Assumed days/Year</th>
<th>Number of Filters(^{278})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary School</td>
<td>400</td>
<td>312</td>
<td>2</td>
</tr>
<tr>
<td>Secondary School</td>
<td>600</td>
<td>312</td>
<td>3</td>
</tr>
<tr>
<td>Quick Service Restaurant</td>
<td>800</td>
<td>312</td>
<td>5</td>
</tr>
<tr>
<td>Full Service Restaurant</td>
<td>780</td>
<td>312</td>
<td>4</td>
</tr>
<tr>
<td>Large Hotel</td>
<td>780</td>
<td>356</td>
<td>4</td>
</tr>
<tr>
<td>Hospital</td>
<td>800</td>
<td>356</td>
<td>4</td>
</tr>
</tbody>
</table>

\(^{275}\) Average dishwashing and faucet water usage taken from Chapter 8, Table 8.3.3 Normalized Annual End Uses of Water in Select Restaurants in Western United States.


\(^{277}\) Commercial Kitchen Loads for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL.

\(^{278}\) Each filter is 20 X 20 inches.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh/\text{Hours} \times CF \]

Where:

- \( \text{Hours} \) = Hours of operation of kitchen exhaust air fan. If not directly available use:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Kitchen Exhaust Fan Annual Operating Hours(^{279})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary School</td>
<td>4,056</td>
</tr>
<tr>
<td>Secondary School</td>
<td>4,056</td>
</tr>
<tr>
<td>Quick Service Restaurant</td>
<td>5,616</td>
</tr>
<tr>
<td>Full Service Restaurant</td>
<td>5,616</td>
</tr>
<tr>
<td>Large Hotel</td>
<td>5,340</td>
</tr>
<tr>
<td>Hospital</td>
<td>3,916</td>
</tr>
</tbody>
</table>

- \( CF \) = Summer Peak Coincidence Factor for measure\(^{280}\):

<table>
<thead>
<tr>
<th>Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Limited Menu</td>
<td>0.32</td>
</tr>
<tr>
<td>Fast Food Expanded Menu</td>
<td>0.41</td>
</tr>
<tr>
<td>Pizza</td>
<td>0.46</td>
</tr>
<tr>
<td>Full Service Limited Menu</td>
<td>0.51</td>
</tr>
<tr>
<td>Full Service Expanded Menu</td>
<td>0.36</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>0.36</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.40</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**

For natural gas hot water heaters:

\[ \Delta \text{Therm} = \frac{(\text{Meal/Day} \times \text{HW/Meal} \times \text{Days/Year}) \times \text{lbs/gal} \times \text{BTU/lb } \cdot ^{\circ}\text{F} \times (\Delta T/\text{filter} \times \text{Qty}_\text{Filter})}{(\eta_{\text{HeaterGas}} \times 100,000)} \]

Where:

- \( \eta_{\text{HeaterGas}} \) = Efficiency of the Gas water heater. If not directly available, use:
  - Actual. If unknown, use the table C404.2 in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

Other variables as above

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

---

\(^{279}\) Exhaust Fan Schedules for listed buildings in U.S. Department of Energy Commercial Reference Building Models of the National Building Stock, NREL

DEEMED O&M COST ADJUSTMENT CALCULATION

O&M savings may result from reduced filter and hood cleaning frequencies. More research should be done to understand any potential savings and the associated value.

MEASURE CODE: CI-HWE-GRTF-V01-160601

REVIEW DEADLINE: 1/1/2024
4.3.10 DHW Boiler Tune-up

DESCRIPTION

Domestic hot water (DHW) boilers provide hot water for bathrooms, kitchens, tubs and other appliances. Several commercial and industrial facilities such as multi-family buildings, lodging and restaurants have a separate hot water boiler serving DHW loads. Unlike space heating boilers, DHW boilers operate year round, which means they have a greater need to be properly maintained and tuned up.

This measure calculates savings for tuning up a DHW boiler to improve its efficiency and reduce its consumption. A boiler tune-up involves cleaning/inspecting burners, burner nozzles and combustion chambers, adjusting air flow and burner gas input to reduce stack temperatures, and checking venting and safety controls. A pre- and post-tune up combustion efficiency ticket (from combustion analyzer) can be used to confirm the improvement in boiler efficiency.

Boilers that serve only a DHW load are eligible for this measure.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years.\textsuperscript{282}

DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr per tune-up.\textsuperscript{283}

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

\[ \Delta \text{Therms} = \frac{((T_{\text{out}} - T_{\text{in}}) \times \text{HotWaterUse}_{\text{Gallon}} \times \gamma_{\text{water}} \times 1 \times (1/\text{Eff}_{\text{before}} - 1/\text{Eff}_{\text{after}}))/100,000}{100,000} \]

Where:

\[ T_{\text{OUT}} \quad = \text{Hot water storage tank temperature} \]
\[ = 125^\circ F \]

\[ T_{\text{IN}} \quad = \text{Incoming water temperature from well or municipal system} \]
\[ = 54^\circ F \textsuperscript{284} \]

\[ \text{HotWaterUse}_{\text{Gallon}} \quad = \text{Estimated annual hot water consumption (gallons)} \]

\[ = \text{Actual if possible to provide reasonable custom estimate. If not, the following methods are provided to develop an estimate}\textsuperscript{285} \]

1. Consumption per usable storage tank capacity

\[ \text{Actual if possible to provide reasonable custom estimate. If not, the following methods are provided to develop an estimate}\textsuperscript{285} \]

\textsuperscript{282} Act on Energy Commercial Technical Reference Manual No. 2010-4, 9.2.2 Gas Boiler Tune-up

\textsuperscript{283} Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012


\textsuperscript{285} Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECs (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%.
= Capacity * Consumption/cap

Where:

Capacity = Usable capacity of hot water storage tank in gallons
= Actual

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Consumption/Cap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>528</td>
</tr>
<tr>
<td>Education</td>
<td>568</td>
</tr>
<tr>
<td>Grocery</td>
<td>528</td>
</tr>
<tr>
<td>Health</td>
<td>788</td>
</tr>
<tr>
<td>Large Office</td>
<td>511</td>
</tr>
<tr>
<td>Large Retail</td>
<td>528</td>
</tr>
<tr>
<td>Lodging</td>
<td>715</td>
</tr>
<tr>
<td>Other Commercial</td>
<td>341</td>
</tr>
<tr>
<td>Restaurant</td>
<td>622</td>
</tr>
<tr>
<td>Small Office</td>
<td>511</td>
</tr>
<tr>
<td>Small Retail</td>
<td>528</td>
</tr>
<tr>
<td>Warehouse</td>
<td>341</td>
</tr>
<tr>
<td>Nursing</td>
<td>672</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>894</td>
</tr>
</tbody>
</table>

2. Consumption per unit area by building type

= (Area/1000) * Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler
= Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Consumption/1,000 sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>4,594</td>
</tr>
<tr>
<td>Education</td>
<td>7,285</td>
</tr>
<tr>
<td>Grocery</td>
<td>697</td>
</tr>
<tr>
<td>Health</td>
<td>24,540</td>
</tr>
<tr>
<td>Large Office</td>
<td>1,818</td>
</tr>
<tr>
<td>Large Retail</td>
<td>1,354</td>
</tr>
<tr>
<td>Lodging</td>
<td>29,548</td>
</tr>
<tr>
<td>Other Commercial</td>
<td>3,941</td>
</tr>
<tr>
<td>Restaurant</td>
<td>44,439</td>
</tr>
<tr>
<td>Small Office</td>
<td>1,540</td>
</tr>
<tr>
<td>Small Retail</td>
<td>6,111</td>
</tr>
<tr>
<td>Warehouse</td>
<td>1,239</td>
</tr>
</tbody>
</table>

286 According to CBECs 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes.
### Building Type

<table>
<thead>
<tr>
<th>Consumption/1,000 sq.ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursing</td>
</tr>
<tr>
<td>Multi-Family</td>
</tr>
</tbody>
</table>

\( \gamma_{\text{water}} \) = Specific weight capacity of water (lb/gal)

\( = 8.33 \text{ lbs/gal} \)

\( 1 \) = Specific heat of water (Btu/lb.\(^\circ\)F)

\( \text{Eff}_{\text{before}} \) = Efficiency of the boiler before tune-up

\( \text{Eff}_{\text{after}} \) = Efficiency of the boiler after tune-up

100,000 = Converts Btu to therms

**Note:** Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the year and take readings at a consistent firing rate for pre and post tune-up.

---

**EXAMPLE**

Tune up of a DHW Boiler heating a 100 gallon storage tank in a nursing home, measuring 80% AFUE prior to tune up and 82.2% AFUE after.

\[
\Delta \text{Therms} = \frac{((T_{\text{out}} - T_{\text{in}}) \times \text{HotWaterUse}_{\text{gallon}} \times \gamma_{\text{water}} \times 1 \times (1/\text{Eff}_{\text{before}} - 1/\text{Eff}_{\text{after}}))/100,000}{100,000}
\]

\[
= \frac{((125 - 54) \times (100 \times 672) \times 8.33 \times 1 \times (1/0.8 - 1/0.822))/100,000}{100,000}
\]

\[
= 13.3 \text{ therms}
\]

---

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** CI-HWE-DBTU-V01-180101

**REVIEW DEADLINE:** 1/1/2024
4.4 HVAC End Use

Many of the commercial HVAC measures use equivalent full load hours (EFLH) to calculate heating and cooling savings. The tables with these values are included in this section and referenced in each measure.

To calculate the updated EFLHs by building type and climate zone provided below, a TAC Subcommittee utilized building energy models originally developed for ComEd, applying some adjustments and additions for new building type models and mechanical systems. Based on comparisons with available field data from Navigant, the EFLH calculation was finalized by the Subcommittee to be the annual total (heating or cooling) output (in Btu) divided by the 95th percentile hourly peak output (heating or cooling) demand (in Btu/hr). This calculation keeps EFLH independent of modeled systems efficiency (which is utilized in the TRM savings calculation) and buffers EFLH value from hourly variances in the modeling that are not representative of actual buildings. See “EFLH Description 2015-02-11.doc” for further explanation.

The building characteristics can be found in the reference table named “EFLH Building Descriptions Updated 2014-11-21.xlsx”.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Heating EFLH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 1</td>
</tr>
<tr>
<td></td>
<td>(Rockford)</td>
</tr>
<tr>
<td>Assembly</td>
<td>1,787</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>1,683</td>
</tr>
<tr>
<td>College</td>
<td>1,530</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>1,481</td>
</tr>
<tr>
<td>Elementary School</td>
<td>1,781</td>
</tr>
<tr>
<td>Garage</td>
<td>985</td>
</tr>
<tr>
<td>Grocery</td>
<td>1,608</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>1,579</td>
</tr>
<tr>
<td>High School</td>
<td>1,845</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>1,764</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>1,788</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td>731</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>1,325</td>
</tr>
<tr>
<td>Hotel/Motel</td>
<td>1,761</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>1,601</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>1,758</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>1,048</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>1,526</td>
</tr>
<tr>
<td>MF - High Rise - Common</td>
<td>1,815</td>
</tr>
<tr>
<td>MF - High Rise - Residential</td>
<td>1,475</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>1,666</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>1,916</td>
</tr>
</tbody>
</table>

287 A full description of the ComEd model development is found in “ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010”
289 Based on model with single duct reheat system with a fixed outdoor air volume.
290 Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors.
291 Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors.
## HVAC End Use

### Heating EFLH

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Zone 1 (Rockford)</th>
<th>Zone 2 (Chicago)</th>
<th>Zone 3 (Springfield)</th>
<th>Zone 4 (Belleville)</th>
<th>Zone 5 (Marion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td>2,020</td>
<td>2,050</td>
<td>1,869</td>
<td>1,252</td>
<td>1,363</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td>2,089</td>
<td>2,132</td>
<td>1,960</td>
<td>1,351</td>
<td>1,487</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>1,528</td>
<td>1,558</td>
<td>1,284</td>
<td>759</td>
<td>846</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td>1,118</td>
<td>1,102</td>
<td>952</td>
<td>505</td>
<td>530</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>1,428</td>
<td>1,425</td>
<td>1,132</td>
<td>692</td>
<td>793</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>1,585</td>
<td>1,587</td>
<td>1,342</td>
<td>855</td>
<td>950</td>
</tr>
<tr>
<td>Religious Building</td>
<td>1,603</td>
<td>1,504</td>
<td>1,440</td>
<td>1,054</td>
<td>1,205</td>
</tr>
<tr>
<td>Restaurant</td>
<td>1,350</td>
<td>1,354</td>
<td>1,216</td>
<td>920</td>
<td>1,091</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>1,392</td>
<td>1,278</td>
<td>1,200</td>
<td>781</td>
<td>891</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>1,456</td>
<td>1,357</td>
<td>1,400</td>
<td>875</td>
<td>1,078</td>
</tr>
<tr>
<td>Warehouse</td>
<td>1,553</td>
<td>1,539</td>
<td>1,369</td>
<td>982</td>
<td>1,139</td>
</tr>
</tbody>
</table>

### Equivalent Full Load Hours for Cooling (EFLH\text{cooling})

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Zone 1 (Rockford)</th>
<th>Zone 2 (Chicago)</th>
<th>Zone 3 (Springfield)</th>
<th>Zone 4 (Belleville)</th>
<th>Zone 5 (Marion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>725</td>
<td>796</td>
<td>937</td>
<td>1,183</td>
<td>932</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>1,475</td>
<td>1,457</td>
<td>1,773</td>
<td>2,110</td>
<td>1,811</td>
</tr>
<tr>
<td>College</td>
<td>475</td>
<td>481</td>
<td>662</td>
<td>746</td>
<td>806</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>1,088</td>
<td>1,067</td>
<td>1,368</td>
<td>1,541</td>
<td>1,371</td>
</tr>
<tr>
<td>Elementary School</td>
<td>725</td>
<td>764</td>
<td>905</td>
<td>1,142</td>
<td>956</td>
</tr>
<tr>
<td>Garage</td>
<td>934</td>
<td>974</td>
<td>1,226</td>
<td>1,582</td>
<td>1,383</td>
</tr>
<tr>
<td>Grocery</td>
<td>1,033</td>
<td>1,000</td>
<td>1,236</td>
<td>1,499</td>
<td>1,286</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>1,282</td>
<td>1,305</td>
<td>1,519</td>
<td>1,767</td>
<td>1,571</td>
</tr>
<tr>
<td>High School</td>
<td>675</td>
<td>721</td>
<td>840</td>
<td>1,060</td>
<td>920</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>4,166</td>
<td>4,275</td>
<td>4,319</td>
<td>4,692</td>
<td>4,445</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>1,751</td>
<td>1,814</td>
<td>2,120</td>
<td>2,411</td>
<td>2,112</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td>1,531</td>
<td>1,592</td>
<td>1,853</td>
<td>2,163</td>
<td>1,876</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>3,245</td>
<td>3,291</td>
<td>3,451</td>
<td>4,128</td>
<td>3,806</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>1,233</td>
<td>1,186</td>
<td>1,436</td>
<td>1,274</td>
<td>1,616</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>1,042</td>
<td>1,019</td>
<td>1,269</td>
<td>1,216</td>
<td>1,418</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>1,010</td>
<td>1,055</td>
<td>1,209</td>
<td>1,453</td>
<td>1,273</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>921</td>
<td>845</td>
<td>1,048</td>
<td>1,779</td>
<td>1,099</td>
</tr>
<tr>
<td>MF - High Rise - Common</td>
<td>914</td>
<td>839</td>
<td>1,055</td>
<td>2,893</td>
<td>1,132</td>
</tr>
<tr>
<td>MF - High Rise - Residential</td>
<td>899</td>
<td>831</td>
<td>1,011</td>
<td>1,569</td>
<td>1,055</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>809</td>
<td>767</td>
<td>992</td>
<td>1,119</td>
<td>993</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>876</td>
<td>745</td>
<td>1,036</td>
<td>1,178</td>
<td>1,010</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td>1,688</td>
<td>1,708</td>
<td>1,811</td>
<td>1,865</td>
<td>1,725</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td>1,454</td>
<td>1,452</td>
<td>1,551</td>
<td>1,568</td>
<td>1,416</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>875</td>
<td>919</td>
<td>1,057</td>
<td>1,275</td>
<td>1,077</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td>1,117</td>
<td>1,170</td>
<td>1,277</td>
<td>1,642</td>
<td>1,412</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>949</td>
<td>1,010</td>
<td>1,182</td>
<td>1,452</td>
<td>1,281</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>883</td>
<td>938</td>
<td>1,072</td>
<td>1,286</td>
<td>1,083</td>
</tr>
<tr>
<td>Religious Building</td>
<td>861</td>
<td>817</td>
<td>967</td>
<td>1,159</td>
<td>1,067</td>
</tr>
<tr>
<td>Building Type</td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
<td>Zone 3 (Springfield)</td>
<td>Zone 4 (Belleville)</td>
<td>Zone 5 (Marion)</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------------------</td>
<td>------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Restaurant</td>
<td>1,074</td>
<td>1,134</td>
<td>1,279</td>
<td>1,627</td>
<td>1,325</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>949</td>
<td>889</td>
<td>1,124</td>
<td>1,367</td>
<td>1,157</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>950</td>
<td>919</td>
<td>1,149</td>
<td>1,351</td>
<td>1,215</td>
</tr>
<tr>
<td>Warehouse</td>
<td>357</td>
<td>338</td>
<td>422</td>
<td>647</td>
<td>533</td>
</tr>
<tr>
<td>Unknown</td>
<td>1,215</td>
<td>1,221</td>
<td>1,408</td>
<td>1,670</td>
<td>1,480</td>
</tr>
</tbody>
</table>
4.4.1 Air Conditioner Tune-up

DESCRIPTION
An air conditioning system that is operating as designed saves energy and provides adequate cooling and comfort to the conditioned space.

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, the efficient equipment is assumed to be a unitary or split system air conditioner least 3 tons and preapproved by program. The measure requires that a certified technician performs the following items:

- Check refrigerant charge
- Identify and repair leaks if refrigerant charge is low
- Measure and record refrigerant pressures
- Measure and record temperature drop at indoor coil
- Clean condensate drain line
- Clean outdoor coil and straighten fins
- Clean indoor and outdoor fan blades
- Clean indoor coil with spray-on cleaner and straighten fins
- Repair damaged insulation – suction line
- Change air filter
- Measure and record blower amp draw

A copy of contractor invoices that detail the work performed to identify tune-up items, as well as additional labor and parts to improve/repair air conditioner performance must be submitted to the program.

DEFINITION OF BASELINE EQUIPMENT
In order for this characterization to apply, the baseline condition is assumed to be an AC system that does not have a standing maintenance contract or a tune up within in the past 36 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 3 years.\(^{292}\)

DEEMED MEASURE COST
The incremental capital cost for this measure is $35\(^{293}\) per ton.

LOADSHAPE
Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

\[
CF_{SSP} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)}
\]

\[
= 91.3\% \quad ^{294}\]

\(^{292}\) 3 years is given for “Clean Condenser Coils – Commercial” and “Clean Evaporator Coils”. DEER2014 EUL Table.
\(^{293}\) Act on Energy Commercial Technical Reference Manual No. 2010-4
\(^{294}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta k\text{Wh} = (k\text{Btu/hr}) \times [(1/\text{EER before}) - (1/\text{EER after})] \times \text{EFLH}
\]

Where:

- \(k\text{Btu/hr}\) = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).
- \text{EER before} = Energy Efficiency Ratio of the baseline equipment prior to tune-up
- \text{EER after} = Energy Efficiency Ratio of the baseline equipment after to tune-up
- \text{EFLH} = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methodology can be used:

\[
\Delta \text{KWh} = \frac{(k\text{Btu/hr})}{\text{EER before}} \times \text{EFLH} \times (1 - \%\text{Savings})
\]

Where:

- \%\text{Savings} = Deemed percent savings per Tune-Up component. These are additive if condenser cleaning, evaporator cleaning and refrigerant charge correction are performed (totals provided below)\(^\text{297}\)

<table>
<thead>
<tr>
<th>Tune-Up Component</th>
<th>% savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condenser Cleaning</td>
<td>6.10%</td>
</tr>
<tr>
<td>Evaporator Cleaning</td>
<td>0.22%</td>
</tr>
<tr>
<td>Refrig. Charge Off. &lt;=20%</td>
<td>0.68%</td>
</tr>
</tbody>
</table>

\(^\text{295}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\(^\text{296}\) In the context of this measure Energy Efficiency Ratio (EER) refers to field-measured steady-state rate of heat energy removal (e.g., cooling capacity) by the equipment in Btuh divided by the steady-state rate of energy input to the equipment in watts. This ratio is expressed in Btuh per watt (Btuh/watt). The cooling capacity may be derived using either refrigerant or air-side measurements. The measurement is performed at the outdoor and indoor environmental conditions that are present at the time the tune-up is being performed, and should be normalized using a correction function to the AHRI 210/240 Standard test conditions. The correction function should be developed based on manufacturer’s performance data. Care must be taken to ensure the unit is fully loaded and operating at or near steady-state. Generally, this requires that the outside air temperature is at least 60°F, and that the unit runs with all stages of cooling enabled for 10 to 15 minutes prior to making measurements. For more information, please see “IL TRM_Normaizing to AHRI Conditions Method”.

\(^\text{297}\) Savings estimates are determined by applying the findings from DNV-GL “Impact Evaluation of 2013-2014 HVAC3 Commercial Quality Maintenance Programs”, April 2016, to simulate the inefficient condition within select eQuest models and across climate zones. The percent savings were consistent enough across building types and climate zones that it was determined appropriate to apply a single set of assumptions for all. See ‘eQuest C&I Tune up Analysis.xlsx’ for more information.
### Air Conditioner Tune-up Component

<table>
<thead>
<tr>
<th>Tune-Up Component</th>
<th>% savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refriger. Charge Off. &gt;20%</td>
<td>8.44%</td>
</tr>
<tr>
<td>Combined (Refrig. Charge Off. &lt;=20%)</td>
<td>7.00%</td>
</tr>
<tr>
<td>Combined (Refrig. Charge Off. &gt;20%)</td>
<td>14.76%</td>
</tr>
</tbody>
</table>

For example, a 12 EER 5-ton rooftop air conditioner on a department store in Rockford receives a tune-up that includes both condenser and evaporator cleaning:

\[
\Delta \text{kWh} = \frac{(5 \times 12)}{12} \times 1392 \times 6.32\% \\
= 440 \text{kWh}
\]

#### Summer Coincident Peak Demand Savings

\[
\Delta \text{kW}_{\text{SSP}} = \left(\frac{k\text{Btu/hr}}{\text{EER}_{\text{before}} - \text{EER}_{\text{after}}}\right) \times \text{CF}_{\text{SSP}} \\
\Delta \text{kW}_{\text{PJM}} = \left(\frac{k\text{Btu/hr}}{\text{EER}_{\text{before}} - \text{EER}_{\text{after}}}\right) \times \text{CF}_{\text{PJM}}
\]

Where:

- \(\text{CF}_{\text{SSP}}\) = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
  
  = 91.3%  

- \(\text{CF}_{\text{PJM}}\) = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)
  
  = 47.8%

Where it is not possible or appropriate to perform Test in and Test out of the equipment, the following deemed methodology can be used:

\[
\Delta \text{kW} = \left(\frac{k\text{Btu/hr}}{\text{EER}_{\text{before}}}\right) \times \%\text{Savings} \times \text{CF}
\]

#### Natural Gas Energy Savings

N/A

#### Water Impact Descriptions and Calculation

N/A

#### Deemed O&M Cost Adjustment Calculation

N/A

#### Measure Code: CI-HVC-ACTU-V04-180101

#### Review Deadline: 1/1/2021

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298 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

299 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
4.4.2 Space Heating Boiler Tune-up

DESCRIPTION

This measure is for a non-residential boiler that provides space heating. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the facility must, as applicable, complete the tune-up requirements listed below, by approved technician:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces.
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and manhole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as requested by on-site personnel.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 3 years.

DEEMED MEASURE COST

The cost of this measure is $0.83/MBtu/hr per tune-up.

---

302 Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012
LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS

\[ \Delta \text{Therms} = \frac{\text{Capacity} \times \text{EFLH} \times ((\text{Eff}_{\text{before}} + \text{Ei}) / \text{Eff}_{\text{before}}) - 1)}{100,000} \]

Where:

- Capacity = Boiler gas input size (Btu/hr)
- EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- \text{Eff}_{\text{before}} = Efficiency of the boiler before the tune-up
- \text{Ei} = Efficiency Improvement of the boiler tune-up measure
- 100,000 = Converts Btu to therms

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

EXAMPLE

For example, a 1050 kBtu boiler in a Chicago high rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

\[ \Delta \text{therms} = \frac{(1,050,000 \times 2050 \times ((0.82 + 0.018) / 0.82 - 1))}{100,000} \]

\[ = 473 \text{ Therms} \]

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-BLRT-V06-160601

REVIEW DEADLINE: 1/1/2022
4.4.3 Process Boiler Tune-up

**DESCRIPTION**

This measure is for a non-residential boiler for process loads. For space heating, see measure 4.4.2. The tune-up will improve boiler efficiency by cleaning and/or inspecting burners, combustion chamber, and burner nozzles. Adjust air flow and reduce excessive stack temperatures, adjust burner and gas input. Check venting, safety controls, and adequacy of combustion air intake. Combustion efficiency should be measured before and after tune-up using an electronic flue gas analyzer.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the facility must, as applicable, complete the tune-up requirements by approved technician, as specified below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Adjust airflow and reduce excessive stack temperatures
- Adjust burner and gas input, manual or motorized draft control
- Check for proper venting
- Complete visual inspection of system piping and insulation
- Check safety controls
- Check adequacy of combustion air intake
- Clean fireside surfaces
- Inspect all refractory. Patch and wash coat as required.
- Inspect gaskets on front and rear doors and replace as necessary.
- Seal and close front and rear doors properly.
- Clean low and auxiliary low water cut-off controls, then re-install using new gaskets.
- Clean plugs in control piping.
- Remove all hand hole and man hole plates. Flush boiler with water to remove loose scale and sediment.
- Replace all hand hole and man hole plates with new gaskets.
- Open feedwater tank manway, inspect and clean as required. Replace manway plate with new gasket.
- Clean burner and burner pilot.
- Check pilot electrode and adjust or replace.
- Clean air damper and blower assembly.
- Clean motor starter contacts and check operation.
- Make necessary adjustments to burner for proper combustion.
- Perform all flame safeguard and safety trip checks.
- Check all hand hole plates and man hole plates for leaks at normal operating temperatures and pressures.
- Troubleshoot any boiler system problems as reQuested by on-site personnel

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition of this measure is a boiler that has not had a tune-up within the past 36 months

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The life of this measure is 3 years

**DEEMED MEASURE COST**

The cost of this measure is $0.83/MBtu/hr per tune-up

---

305 Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012
DEEMED O&M COST ADJUSTMENTS
N/A

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS

\[ \Delta \text{Therms} = \left( \frac{N_{gi} \times 8766 \times UF}{100} \right) \times (1 - \frac{Eff_{pre}}{Eff_{measured}}) \]

Where:

- N_{gi} = Boiler gas input size (kBtu/hr)
- UF = custom
- Eff_{pre} = Boiler Combustion Efficiency Before Tune-Up
- Eff_{measured} = Boiler Combustion Efficiency After Tune-Up

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

\[ N_{gi} \times 100 \times 8766 \] = conversion from kBtu to therms

8766 = hours a year

---

EXAMPLE
For example, a 80% 1050 kBtu boiler is tuned-up resulting in final efficiency of 81.3%:
\[ \Delta \text{therms} = \frac{(1050 \times 8766 \times 0.419)}{100} \times (1 - \frac{0.80}{0.813}) \]
\[ = 617 \text{ therms} \]

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-PBTU-V05-160601

REVIEW DEADLINE: 1/1/2022
4.4.4 Boiler Lockout/Reset Controls

**DESCRIPTION**

This measure relates to improving combustion efficiency by adding controls to non-residential building heating boilers to vary the boiler entering water temperature relative to heating load as a function of the outdoor air temperature to save energy. Energy is saved by increasing the temperature difference between the water temperature entering the boiler in the boiler's heat exchanger and the boiler's burner flame temperature. The flame temperature remains the same while the water temperature leaving the boiler decreases with the decrease in heating load due to an increase in outside air temperature. A lockout temperature is also set to prevent the boiler from turning on when it is above a certain temperature outdoors.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

Natural gas customer adding boiler reset controls capable of resetting the boiler supply water temperature in an inverse linear fashion with outdoor air temperature. Boiler lockout temperatures should be set to 55 °F at this time as well, to turn the boiler off when the temperature goes above a certain setpoint.

**DEFINITION OF BASELINE EQUIPMENT**

Existing boiler without boiler reset controls, any size with constant hot water flow.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The life of this measure is 20 years.

**DEEMED MEASURE COST**

The cost of this measure is $612.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

<table>
<thead>
<tr>
<th>Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CALCULATION OF SAVINGS</strong></td>
</tr>
</tbody>
</table>

| **ELECTRIC ENERGY SAVINGS** |

N/A

| **SUMMER COINCIDENT PEAK DEMAND SAVINGS** |

N/A

---


**Natural Gas Energy Savings**

\[ \Delta \text{Therms} = \text{Binput} \times \text{SF} \times \text{EFLH} / (100) \]

Where:

- Binput = Boiler Input Capacity (kBtu/hr)
  - custom
- SF = Savings factor
  - 8\%\(^{309}\) or custom
- EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- 100 = conversion from kBtu to therms

**Example**

For example, a 800 kBtu/hr boiler at a restaurant in Rockford, IL

\[ \Delta \text{Therms} = 800 \times 0.08 \times 1,350 / (100) \]

\[ = 864 \text{ Therms} \]

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: CI-HVC-BLRC-V03-150601**

**Review Deadline: 1/1/2021**

---

\(^{309}\) Savings factor is the estimate of annual gas consumption that is saved due to adding boiler reset controls. The CLEAResults uses a boiler tuneup savings value derived from Xcel Energy "DSM Biennial Plan-Technical Assumptions," Colorado. Focus on Energy uses 8\%, citing multiple sources. Vermont Energy Investment Corporation's boiler reset savings estimates for custom projects further indicate 8\% savings estimate is better reflection of actual expected savings.
4.4.5 Condensing Unit Heaters

**DESCRIPTION**

This measure applies to a gas fired condensing unit heater installed in a commercial application. This measure was developed to be applicable to the following program types: TOS, NC. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to be a condensing unit heater up to 300 MBH with a Thermal Efficiency > 90% and the heater must be vented, and condensate drained per manufacturer specifications. The unit must be replacing existing natural gas equipment.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline condition is assumed to be a non-condensing natural gas unit heater at end of life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years\textsuperscript{310}

**DEEMED MEASURE COST**

The incremental capital cost for a unit heater is $676\textsuperscript{311}

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

The annual natural gas energy savings from this measure is a deemed value equaling 266 Therms.

\textsuperscript{310}\textsuperscript{DEER 2008}

\textsuperscript{311}\textsuperscript{ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011}
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-CUHT-V01-120601

REVIEW DEADLINE: 1/1/2019
4.4.6 Electric Chiller

**DESCRIPTION**

This measure relates to the installation of a new electric chiller meeting the efficiency standards presented below. This measure could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in an existing building (i.e. time of sale). Only single-chiller applications should be assessed with this methodology. The characterization is not suited for multiple chillers projects or chillers equipped with variable speed drives (VSDs).

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

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to exceed the efficiency requirements defined by the program.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline equipment is assumed to meet the efficiency requirements within Table 403.2.3(7) of either the 2012 or the 2015 IECC (applicable from 01/01/2016), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 20 years 312.

**DEEMED MEASURE COST**

The incremental capital cost for this measure is provided below.

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category</th>
<th>Incremental Cost ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooled, electrically operated</td>
<td>All capacities</td>
<td>$127/ton 313</td>
</tr>
<tr>
<td>Water cooled, electrically operated, positive</td>
<td>All capacities</td>
<td>$22/ton 314</td>
</tr>
<tr>
<td>displacement (reciprocating)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water cooled, electrically operated, positive</td>
<td>&lt; 150 tons</td>
<td>$351/ton 315</td>
</tr>
<tr>
<td>displacement (rotary screw and scroll)</td>
<td>150 tons and &lt; 300 tons</td>
<td>$127/ton</td>
</tr>
<tr>
<td></td>
<td>&gt;= 300 tons</td>
<td>$87/ton</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

Loadshape C03 - Commercial Cooling

---


313 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, “Cost Values and Summary Documentation”, California Public Utilities Commission, December 16, 2008. Calculated as the simple average of screw and reciprocating air-cooled chiller incremental costs from DEER2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the *average* savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \]

\[ = 91.3\% \] \(^{316}\)

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \]

\[ = 47.8\% \] \(^{317}\)

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta k\text{WH} = \text{TONS} \times ((\text{IPLV}_{\text{base}}) - (\text{IPLV}_{\text{ee}})) \times \text{EFLH} \]

Where:

- **TONS** = chiller nominal cooling capacity in tons (note: 1 ton = 12,000 Btu/hr)
- **IPLV_{\text{base}}** = efficiency of baseline equipment expressed as Integrated Part Load Value (kW/ton). Chiller units are dependent on chiller type. See Chiller Units, Conversion Values and Baseline Efficiency Values by Chiller Type and Capacity in the Reference Tables section.
- **IPLV_{\text{ee}}** = efficiency of high efficiency equipment expressed as Integrated Part Load Value (kW/ton) \(^{318}\)
- **EFLH** = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.

For example, a 100 ton air-cooled electrically operated chiller with IPLV of 14 EER (0.86 kW/ton) and baseline EER of 12.5 (0.96 kW/ton) in a low-rise office building in Rockford with a building permit dated on 1/1/2015 would save:

\[ \Delta k\text{WH} = 100 \times ((0.96) - (0.86)) \times 949 \]

\[ = 9,490 \text{ kWh} \]

---

\(^{316}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

\(^{317}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\(^{318}\) Integrated Part Load Value is a seasonal average efficiency rating calculated in accordance with ARI Standard 550/590. It may be calculated using any measure of efficiency (EER, kW/ton, COP), but for consistency with IECC 2012, it is expressed in terms of IPLV here.

\(^{319}\) Can determine IPLV from standard testing or looking at engineering specs for design conditions. Standard data is available from AHRnetI.org. http://www.ahrinet.org/
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW_{SSP} = \text{TONS} \times ((\text{PEbase}) - (\text{PEee})) \times CF_{SSP} \]

\[ \Delta kW_{PJM} = \text{TONS} \times ((\text{PEbase}) - (\text{PEee})) \times CF_{PJM} \]

Where:

- \( \text{PEbase} \) = Peak efficiency of baseline equipment expressed as Full Load (kW/ton)
- \( \text{PEee} \) = Peak efficiency of high efficiency equipment expressed as Full Load (kW/ton)
- \( \text{CF}_{SSP} \) = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
- \( \text{CF}_{PJM} \) = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

For example, a 100 ton air-cooled electrically operated chiller with a peak efficiency of 1.05 kW/ton and a baseline peak efficiency of 1.2 kW/ton would save:

\[ \Delta kW_{SSP} = 100 \times (1.2 - 1.05) \times 0.913 \]

\[ = 13.7 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Chillers Ratings- Chillers are rated with different units depending on equipment type as shown below

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooled, electrically operated</td>
<td>EER</td>
</tr>
<tr>
<td>Water cooled, electrically operated, positive displacement (reciprocating)</td>
<td>kW/ton</td>
</tr>
<tr>
<td>Water cooled, electrically operated, positive displacement (rotary screw and scroll)</td>
<td>kW/ton</td>
</tr>
</tbody>
</table>

In order to convert chiller equipment ratings to IPLV the following relationships are provided

- kW/ton = 12 / EER
- kW/ton = 12 / (COP x 3.412)
- COP = EER / 3.412
COP = 12 / (kW/ton) / 3.412

EER = 12 / kW/ton

EER = COP x 3.412

2012 IECC Baseline Efficiency Values by Chiller Type and Capacity

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>UNITS</th>
<th>BEFORE 1/1/2010</th>
<th>AS OF 1/1/2010</th>
<th>TEST PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>FULL LOAD</td>
<td>IPLV</td>
<td>FULL LOAD</td>
</tr>
<tr>
<td>Air-cooled chillers</td>
<td>&lt; 150 tons</td>
<td>EER</td>
<td>≥ 9.562</td>
<td>≥ 9.562</td>
<td>≥ 12.500</td>
</tr>
<tr>
<td></td>
<td>≥ 150 tons</td>
<td>EER</td>
<td>≥ 10.4</td>
<td>16</td>
<td>≥ 12.750</td>
</tr>
<tr>
<td>Air cooled without condenser, electrical operated</td>
<td>All capacities</td>
<td>EER</td>
<td>≥ 10.584</td>
<td>≥ 11.782</td>
<td></td>
</tr>
<tr>
<td>Water cooled, electrically operated, reciprocating</td>
<td>All capacities</td>
<td>kW/ton</td>
<td>≤ 0.837</td>
<td>≤ 0.696</td>
<td></td>
</tr>
<tr>
<td>Water cooled, electrically operated, positive displacement</td>
<td>&lt; 75 tons and &lt; 150 tons</td>
<td>kW/ton</td>
<td>≤ 0.790</td>
<td>≤ 0.780</td>
<td>≤ 0.630</td>
</tr>
<tr>
<td></td>
<td>≥ 75 tons and ≥ 150 tons</td>
<td>kW/ton</td>
<td>≤ 0.790</td>
<td>≤ 0.775</td>
<td>≤ 0.615</td>
</tr>
<tr>
<td></td>
<td>≥ 300 tons and &lt; 600 tons</td>
<td>kW/ton</td>
<td>≤ 0.639</td>
<td>≤ 0.571</td>
<td>≤ 0.629</td>
</tr>
<tr>
<td>Water cooled, electrically operated, centrifugal</td>
<td>&lt; 150 tons and &lt; 300 tons</td>
<td>kW/ton</td>
<td>≤ 0.703</td>
<td>≤ 0.669</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 150 tons and ≥ 300 tons</td>
<td>kW/ton</td>
<td>≤ 0.634</td>
<td>≤ 0.596</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 600 tons</td>
<td>kW/ton</td>
<td>≤ 0.576</td>
<td>≤ 0.549</td>
<td>≤ 0.570</td>
</tr>
<tr>
<td>Air cooled, absorption single effect</td>
<td>All capacities</td>
<td>CCP</td>
<td>≥ 0.600</td>
<td>≥ 0.600</td>
<td>≥ 0.600</td>
</tr>
<tr>
<td>Water cooled, absorption single effect</td>
<td>All capacities</td>
<td>CCP</td>
<td>≥ 0.700</td>
<td>≥ 0.700</td>
<td>≥ 0.700</td>
</tr>
<tr>
<td>Absorption double effect, indirect fired</td>
<td>All capacities</td>
<td>CCP</td>
<td>≥ 1.000</td>
<td>≥ 1.050</td>
<td>≥ 1.000</td>
</tr>
<tr>
<td>Absorption double effect, direct fired</td>
<td>All capacities</td>
<td>CCP</td>
<td>≥ 1.000</td>
<td>≥ 1.000</td>
<td>≥ 1.000</td>
</tr>
</tbody>
</table>

For SI: 1 ton = 3517 W, 1 British thermal unit per hour = 0.2931 W, °C = (°F - 32) / 1.8.
NA = Not applicable, not to be used for compliance; NR = No requirement.
a. The centrifugal chiller equipment requirements, after adjustment in accordance with Section C403.2.3.1 or Section C403.3.2, do not apply to chillers used in low-temperature applications where the design leaving fluid temperatures is less than 38°F. The requirements do not apply to positive displacement chillers with leaving fluid temperatures less than equal to 32°F. The requirements do not apply to absorption chillers with design leaving fluid temperatures less than 40°F.
b. Compliance with this standard can be obtained by meeting the minimum requirements of Path A or B. However, both the full load and IPLV shall be met to fulfill the requirements of Path A or B.
c. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
## 2015 IECC Baseline Efficiency Values by Chiller Type and Capacity

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Size Category</th>
<th>Units</th>
<th>Before 1/1/2015</th>
<th>As of 1/1/2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Path A</td>
<td>Path B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Path A</td>
<td>Path B</td>
</tr>
<tr>
<td>Air-cooled chillers</td>
<td>&lt; 150 Tons</td>
<td>EER</td>
<td>≥ 9.561 FL</td>
<td>NA*</td>
</tr>
<tr>
<td></td>
<td>≥ 150 Tons</td>
<td>EER</td>
<td>≥ 12.500 IPLV</td>
<td>NA*</td>
</tr>
<tr>
<td>Air-cooled without condenser,</td>
<td>All capacities</td>
<td>EER</td>
<td>Air-cooled chillers without condenser shall be rated with matching condensers and complying with air-cooled chiller efficiency requirement.</td>
<td></td>
</tr>
<tr>
<td>electrically operated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-cooled, electrically</td>
<td>&lt; 75 Tons</td>
<td>kW/ton</td>
<td>≤ 0.789 FL</td>
<td>≤ 0.800 FL</td>
</tr>
<tr>
<td>operated, positive displacement</td>
<td>≥ 75 tons and &lt; 150 tons</td>
<td>kW/ton</td>
<td>≤ 0.775 FL</td>
<td>≤ 0.770 FL</td>
</tr>
<tr>
<td></td>
<td>≥ 150 tons and &lt; 300 tons</td>
<td>kW/ton</td>
<td>≤ 0.615 FL</td>
<td>≤ 0.584 FL</td>
</tr>
<tr>
<td></td>
<td>≥ 300 tons and &lt; 600 tons</td>
<td>kW/ton</td>
<td>≤ 0.680 FL</td>
<td>≤ 0.718 FL</td>
</tr>
<tr>
<td></td>
<td>≥ 600 tons</td>
<td>kW/ton</td>
<td>≤ 0.580 FL</td>
<td>≤ 0.540 FL</td>
</tr>
<tr>
<td>Water-cooled, electrically</td>
<td>&lt; 150 Tons</td>
<td>kW/ton</td>
<td>≤ 0.654 FL</td>
<td>≤ 0.639 FL</td>
</tr>
<tr>
<td>operated centrifugal,</td>
<td>≥ 150 tons and &lt; 300 tons</td>
<td>kW/ton</td>
<td>≤ 0.594 FL</td>
<td>≤ 0.550 FL</td>
</tr>
<tr>
<td></td>
<td>≥ 300 tons and &lt; 600 tons</td>
<td>kW/ton</td>
<td>≤ 0.574 FL</td>
<td>≤ 0.530 FL</td>
</tr>
<tr>
<td></td>
<td>≥ 600 tons</td>
<td>kW/ton</td>
<td>≤ 0.579 FL</td>
<td>≤ 0.590 FL</td>
</tr>
<tr>
<td>Air-cooled, absorption, single</td>
<td>All capacities</td>
<td>COP</td>
<td>≥ 0.600 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>effect</td>
<td></td>
<td></td>
<td>≥ 0.600 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>Water-cooled absorption, single</td>
<td>All capacities</td>
<td>COP</td>
<td>≥ 0.700 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>effect</td>
<td></td>
<td></td>
<td>≥ 0.700 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>Absorption, double effect,</td>
<td>All capacities</td>
<td>COP</td>
<td>≥ 1.000 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>indirect fired</td>
<td></td>
<td></td>
<td>≥ 1.000 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>Absorption double effect, direct</td>
<td>All capacities</td>
<td>COP</td>
<td>≥ 1.000 FL</td>
<td>NA*</td>
</tr>
<tr>
<td>fired</td>
<td></td>
<td></td>
<td>≥ 1.000 FL</td>
<td>NA*</td>
</tr>
</tbody>
</table>

**Measure Code:** CI-HVC-Chill-V05-180101

**Review Deadline:** 1/1/2022
4.4.7 ENERGY STAR and CEE Tier 1 Room Air Conditioner

DESCRIPTION

This measure relates to the purchase and installation of a room air conditioning unit that meets either the ENERGY STAR or CEE TIER 1 minimum qualifying efficiency specifications, in place of a baseline unit meeting minimum Federal Standard efficiency ratings presented below:320

<table>
<thead>
<tr>
<th>Product Class (Btu/H)</th>
<th>Federal Standard EER, with louvered sides</th>
<th>Federal Standard EER, without louvered sides</th>
<th>ENERGY STAR EER, with louvered sides</th>
<th>ENERGY STAR EER, without louvered sides</th>
<th>CEE TIER 1 EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 8,000</td>
<td>9.7</td>
<td>9</td>
<td>10.7</td>
<td>9.9</td>
<td>11.2</td>
</tr>
<tr>
<td>8,000 to 13,999</td>
<td>9.8</td>
<td>8.5</td>
<td>10.8</td>
<td>9.4</td>
<td>11.3</td>
</tr>
<tr>
<td>14,000 to 19,999</td>
<td>9.7</td>
<td>8.5</td>
<td>10.7</td>
<td>9.4</td>
<td>11.2</td>
</tr>
<tr>
<td>&gt;= 20,000</td>
<td>8.5</td>
<td>8.5</td>
<td>9.4</td>
<td>9.4</td>
<td>9.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Casement</th>
<th>Federal Standard (EER)</th>
<th>ENERGY STAR (EER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casement-only</td>
<td>8.7</td>
<td>9.6</td>
</tr>
<tr>
<td>Casement-slider</td>
<td>9.5</td>
<td>10.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reverse Cycle - Product Class (Btu/H)</th>
<th>Federal Standard EER, with louvered sides</th>
<th>Federal Standard EER, without louvered sides</th>
<th>ENERGY STAR EER, with louvered sides</th>
<th>ENERGY STAR EER, without louvered sides</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 14,000</td>
<td>N/A</td>
<td>8.5</td>
<td>N/A</td>
<td>9.4</td>
</tr>
<tr>
<td>&gt;= 14,000</td>
<td>N/A</td>
<td>8</td>
<td>N/A</td>
<td>8.8</td>
</tr>
<tr>
<td>&lt; 20,000</td>
<td>9</td>
<td>N/A</td>
<td>9.9</td>
<td>N/A</td>
</tr>
<tr>
<td>&gt;= 20,000</td>
<td>8.5</td>
<td>N/A</td>
<td>9.4</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR efficiency standards presented above.

Side louvers that extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as “through-the-wall” or “built-in” models.
Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.
Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.
Reverse cycle refers to the heating function found in certain room air conditioner models.
http://www.energystar.gov/ia/partners/product_specs/program_reqs/room_air_conditioners_prog_req.pdf
**DEFINITION OF BASELINE EQUIPMENT**

The baseline assumption is a new room air conditioning unit that meets the current minimum federal efficiency standards presented above.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 9 years.\(^{321}\)

**DEEMED MEASURE COST**

The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $80 for a CEE TIER 1 unit.\(^{322}\)

**LOADSHAPE**

Loadshape C03 - Commercial Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

\[
\text{CF}_{SSP} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)}
\]
\[
= 91.3\% ^{323}
\]
\[
\text{CF}_{PJM} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)}
\]
\[
= 47.8\% ^{324}
\]

**Algorithm**

**CALCULATION OF SAVINGS**

**ENERGY SAVINGS**

\[
\Delta k\text{Wh} = \left(\text{FLH}_{\text{RoomAC}} \times \text{Btu/H} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}})\right)/1000
\]

Where:

\[
\text{FLH}_{\text{RoomAC}} = \text{Full Load Hours of room air conditioning unit}
\]
\[
\text{dependent on location} ^{325}
\]

---


\(^{322}\) Based on field study conducted by Efficiency Vermont

\(^{323}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

\(^{324}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

### 4.4.7 ENERGY STAR and CEE Tier 1 Room Air Conditioner

#### Zone FLH<sub>RoomAC</sub>

<table>
<thead>
<tr>
<th>Zone</th>
<th>FLH&lt;sub&gt;RoomAC&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>253</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>254</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>310</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>391</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>254</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Btu/H</th>
<th>= Size of unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= Actual. If unknown assume 8500 Btu/hr&lt;sup&gt;326&lt;/sup&gt;</td>
</tr>
<tr>
<td>EERbase</td>
<td>= Efficiency of baseline unit</td>
</tr>
<tr>
<td></td>
<td>= As provided in tables above</td>
</tr>
<tr>
<td>EERee</td>
<td>= Efficiency of ENERGY STAR or CEE Tier 1 unit</td>
</tr>
<tr>
<td></td>
<td>= Actual. If unknown assume minimum qualifying standard as provided in tables above</td>
</tr>
</tbody>
</table>

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford:

\[
\Delta kW_{\text{ENERGY STAR}} = \frac{(253 \times 8500 \times (1/9.8 - 1/10.8))}{1000} \\
= 20.3 \text{ kWh}
\]

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta kW = \frac{Btu/H \times ((1/EERbase - 1/EERee))}{1000} \times CF
\]

Where:

- **CF<sub>SSP</sub>** = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
  - = 91.3%<sup>327</sup>
- **CF<sub>PJM</sub>** = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)
  - = 47.8%<sup>328</sup>

Other variable as defined above

For example for an 8,500 Btu/H capacity ENERGY STAR unit, with louvered sides, in Rockford during system peak

\[
\Delta kW_{\text{ENERGY STAR}} = \frac{(8500 \times (1/9.8 - 1/10.8))}{1000} \times 0.913 \\
= 0.073 \text{ kW}
\]

### FOSSIL FUEL SAVINGS

N/A

---

<sup>326</sup> Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

<sup>327</sup> Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

<sup>328</sup> Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-ESRA-V01-120601

REVIEW DEADLINE: 1/1/2019
4.4.8 Guest Room Energy Management (PTAC & PTHP)

DESCRIPTION

This measure applied to the installation of a temperature setback and lighting control system for individual guest rooms. The savings are achieved based on Guest Room Energy Management’s (GREM’s) ability to automatically adjust the guest room’s set temperatures and control the HVAC unit for various occupancy modes.

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

DEFINITION OF EFFICIENT EQUIPMENT

Guest room temperature set point must be controlled by automatic occupancy detectors or keycard that indicates the occupancy status of the room. During unoccupied periods the default setting for controlled units differs by at least 5 degrees from the operating set point. Theoretically, the control system may also be tied into other electric loads, such as lighting and plug loads to shut them off when occupancy is not sensed. This measure bases savings on improved HVAC controls. If system is connected to lighting and plug loads, additional savings would be realized. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.

DEFINITION OF BASELINE EQUIPMENT

Guest room energy management thermostats replace manual heating/cooling temperature set-point and fan On/Off/Auto thermostat controls. Two possible baselines exist based on whether housekeeping staff are directed to set-back (or turn off) thermostats when rooms are not rented.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for GREM is 15 years329.

DEEMED MEASURE COST

$260/unit

The IMC documented for this measure is $260 per room HVAC controller, which is the cost difference between a non-programmable thermostat and a GREM330.

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

A coincidence factor is not used in the determination of coincident peak kW savings.

---

329 DEER 2008 value for energy management systems
330 This value was extracted from Smart Ideas projects in PY1 and PY2.
**Algorithm**

**CALCULATION OF SAVINGS**

Below are the annual kWh savings per installed EMS for different sizes and types of HVAC units. The savings are achieved based on GREM’s ability to automatically adjust the guest room’s set temperatures and control the HVAC unit to maintain set temperatures for various occupancy modes. Note that care should be taken in selecting a value consistent with actual baseline conditions (e.g. whether housekeeping staff are directed to set-back/turn-off the thermostats when rooms are unrented). Different values are provided for Motels and Hotels since significant differences in shell performance, number of external walls per room and typical heating and cooling efficiencies result in significantly different savings estimates. Energy savings estimates are derived using a prototypical EnergyPlus simulation of a motel and a hotel\(^{331}\). Model outputs are normalized to the installed capacity and reported here as kWh/Ton, coincident peak kW/Ton and Therms/Ton.

**ELECTRIC ENERGY SAVINGS**

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Heating Source</th>
<th>Baseline</th>
<th>Electric Savings (kWh/Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 (Rockford)</strong></td>
<td>PTAC w/ Electric Resistance Heating</td>
<td>Housekeeping Setback</td>
<td>744</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>1,786</td>
</tr>
<tr>
<td></td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>PTHP</td>
<td>Housekeeping Setback</td>
<td>385</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>986</td>
</tr>
<tr>
<td><strong>2 (Chicago)</strong></td>
<td>PTAC w/ Electric Resistance Heating</td>
<td>Housekeeping Setback</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>1,582</td>
</tr>
<tr>
<td></td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>163</td>
</tr>
<tr>
<td></td>
<td>PTHP</td>
<td>Housekeeping Setback</td>
<td>211</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>798</td>
</tr>
<tr>
<td><strong>3 (Springfield)</strong></td>
<td>PTAC w/ Electric Resistance Heating</td>
<td>Housekeeping Setback</td>
<td>462</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>1,382</td>
</tr>
<tr>
<td></td>
<td>PTAC w/ Gas Heating</td>
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\(^{331}\) For motels, see S. Keates, ADM Associates Workpaper: “Suggested Revisions to Guest Room Energy Management (PTAC & PTHP)”, 11/14/2013 and spreadsheet summarizing the results: ‘GREM Savings Summary_IL TRM_1_22_14.xlsx’. In 2014 the hotel models were also run to compile results, rather than by applying adjustment factors to the motel results as had been done in V3.0 of the TRM. The updated values can be found in ‘GREM Savings Summary (Hotel)_IL TRM_10_16_14.xls’.
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**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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### Natural Gas Energy Savings

For PTACs with gas heating:

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### Hotel Natural Gas Energy Savings

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Heating Source</th>
<th>Baseline</th>
<th>Gas Savings (Therms/Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>6.4</td>
</tr>
<tr>
<td></td>
<td>Central Hot Water Fan Coil w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>6.4</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Central Hot Water Fan Coil w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>6.5</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No Housekeeping Setback</td>
<td>4.1</td>
</tr>
<tr>
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<td>Housekeeping Setback</td>
<td>2.6</td>
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</table>
### Hotel Natural Gas Energy Savings

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Heating Source</th>
<th>Baseline</th>
<th>Gas Savings (Therms/Ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (Belleville)</td>
<td>Central Hot Water Fan Coil w/ Gas Heating</td>
<td>No Housekeeping Setback</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>2.5</td>
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<td>Central Hot Water Fan Coil w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>2.5</td>
</tr>
<tr>
<td>5 (Marion-Williamson)</td>
<td>PTAC w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>2.1</td>
</tr>
<tr>
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<td>Central Hot Water Fan Coil w/ Gas Heating</td>
<td>Housekeeping Setback</td>
<td>2.1</td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-GREM-V05-150601**

**REVIEW DEADLINE: 1/1/2022**
4.4.9 Heat Pump Systems

DESCRIPTION
This measure applies to the installation of high-efficiency air cooled, water source, ground water source, and ground source heat pump systems. This measure could apply to replacing an existing unit at the end of its useful life, or installation of a new unit in a new or existing building.

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

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, the efficient equipment is assumed to be a high-efficiency air cooled, water source, ground water source, or ground source heat pump system that exceeds the energy efficiency requirements of the 2012 or 2015 (applicable from 01/01/2016) International Energy Conservation Code (IECC), depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

DEFINITION OF BASELINE EQUIPMENT
In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air cooled, water source, ground water source, or ground source heat pump system that meets the energy efficiency requirements of the 2012 or 2015 IECC, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015). Note the Time of Sale baseline is assumed to be IECC 2015. The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 15 years\(^{332}\) except for geothermal heat pump systems which have an expected measures life of 25 years\(^{333}\).

DEEMED MEASURE COST
For analysis purposes, the incremental capital cost for this measure is assumed as $100 per ton for air-cooled units.\(^{334}\) The incremental cost for all other equipment types should be determined on a site-specific basis.

LOADSHAPE
Loadshape C05 - Commercial Electric Heating and Cooling

COINCIDENCE FACTOR
The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

\[
\text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)}
\]

\[
\text{CF}_{\text{SSP}} = 91.3\% \quad ^{335}\]


\(^{333}\)System life of indoor components as per DOE estimate http://energy.gov/energysaver/articles/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP.

\(^{334}\)Based on a review of TRM incremental cost assumptions from Vermont, Wisconsin, and California.

\(^{335}\)Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.
CF_{PJM} = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)
= 47.8% \textsuperscript{336}

Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For units with cooling capacities less than 65 kBTU/hr:

$$\Delta \text{kWh} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\text{Annual kWh Savings}_{\text{cool}} = (\text{kBTU/\text{hr}}_{\text{cool}}) \times [(1/\text{SEERbase}) - (1/\text{SEERee})] \times \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBTU/\text{hr}}_{\text{heat}}) \times [(1/\text{HSPFbase}) - (1/\text{HSPFee})] \times \text{EFLH}_{\text{heat}}$$

For units with cooling capacities equal to or greater than 65 kBTU/hr:

$$\Delta \text{kWh} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}}$$

$$\text{Annual kWh Savings}_{\text{cool}} = (\text{kBTU/\text{hr}}_{\text{cool}}) \times [(1/\text{EERbase}) - (1/\text{EERee})] \times \text{EFLH}_{\text{cool}}$$

$$\text{Annual kWh Savings}_{\text{heat}} = (\text{kBTU/\text{hr}}_{\text{heat}})/3.412 \times [(1/\text{COPbase}) - (1/\text{COPee})] \times \text{EFLH}_{\text{heat}}$$

Where:

- $\text{kBTU/\text{hr}}_{\text{cool}}$ = capacity of the cooling equipment in kBTU per hour (1 ton of cooling capacity equals 12 kBTU/hr).
- Actual installed
- SEERbase = Seasonal Energy Efficiency Ratio of the baseline equipment
  = SEER from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015).
- SEERee = Seasonal Energy Efficiency Ratio of the energy efficient equipment.
  = Actual installed
- EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use.
- HSPFbase = Heating Seasonal Performance Factor of the baseline equipment
  = HSPF from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015).
- HSPFee = Heating Seasonal Performance Factor of the energy efficient equipment.
  = Actual installed. If rating is COP, HSPF = COP * 3.413
- EFLH_{heat} = heating mode equivalent full load hours are provided in section 4.4 HVAC End Use.
- EERbase = Energy Efficiency Ratio of the baseline equipment

\textsuperscript{336} Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
= EER from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015). For air-cooled units < 65 kBtu/hr, assume the following conversion from SEER to EER for calculation of peak savings:\(^{337}\)

\[
EER = (-0.02 \times SEER^2) + (1.12 \times SEER)
\]

EERee = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EERee is unknown, assume the conversion from SEER to EER as provided above.

= Actual installed

kBtu/hr\text{heat} = capacity of the heating equipment in kBtu per hour.

= Actual installed

3.412 = Btu per Wh.

COPbase = coefficient of performance of the baseline equipment

= COP from tables below, based on the applicable IECC on the date of the building permit (if unknown assume IECC 2015). If rating is HSPF, COP = HSPF / 3.413

COPee = coefficient of performance of the energy efficient equipment.

= Actual installed

Minimum Efficiency Requirements: 2012 IECC

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>HEATING SECTION TYPE</th>
<th>MINIMUM EFFICIENCY</th>
<th>TEST PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooled (cooling mode)</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>13.0 SEER</td>
</tr>
<tr>
<td>Through-the-wall, air cooled</td>
<td>≤ 30,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>13.0 SEER</td>
</tr>
<tr>
<td>Single-duct high-velocity air cooled</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>10.0 SEER</td>
</tr>
<tr>
<td></td>
<td>≥ 65,000 Btu/h</td>
<td>Electric Resistance</td>
<td>Split System and Single Package</td>
<td>11.0 EER 11.2 IEER</td>
</tr>
<tr>
<td></td>
<td>&lt; 135,000 Btu/h</td>
<td>Electric Resistance</td>
<td>Split System and Single Package</td>
<td>10.8 EER 11.0 IEER</td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h</td>
<td>Electric Resistance</td>
<td>Split System and Single Package</td>
<td>10.6 EER 10.7 IEER</td>
</tr>
<tr>
<td></td>
<td>&lt; 240,000 Btu/h</td>
<td>Electric Resistance</td>
<td>Split System and Single Package</td>
<td>10.4 EER 10.5 IEER</td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Btu/h</td>
<td>Electric Resistance</td>
<td>Split System and Single Package</td>
<td>9.5 EER 9.6 IEER</td>
</tr>
<tr>
<td>Water source (cooling mode)</td>
<td>&lt; 17,000 Btu/h</td>
<td>All</td>
<td>86°F entering water</td>
<td>11.2 EER</td>
</tr>
<tr>
<td></td>
<td>≥ 17,000 Btu/h</td>
<td>All</td>
<td>86°F entering water</td>
<td>12.0 EER</td>
</tr>
<tr>
<td></td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>86°F entering water</td>
<td>12.0 EER</td>
</tr>
<tr>
<td>Water-source water to water (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>86°F entering water</td>
<td>10.6 EER 10.6 EER</td>
</tr>
<tr>
<td>Ground water source (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>59°F entering water</td>
<td>16.2 EER</td>
</tr>
<tr>
<td></td>
<td>&gt; 135,000 Btu/h</td>
<td>All</td>
<td>77°F entering water</td>
<td>13.4 EER</td>
</tr>
<tr>
<td>Ground water source brine to water (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>77°F entering fluid</td>
<td>12.1 EER</td>
</tr>
<tr>
<td>Air cooled (heating mode)</td>
<td>&lt; 65,000 Btu/h</td>
<td>—</td>
<td>Split System</td>
<td>7.7 HSPF</td>
</tr>
<tr>
<td>Through-the-wall, (air cooled, heating mode)</td>
<td>≤ 30,000 Btu/h</td>
<td>—</td>
<td>Split System</td>
<td>7.4 HSPF</td>
</tr>
<tr>
<td>Single-duct high velocity (air cooled, heating mode)</td>
<td>&lt; 65,000 Btu/h</td>
<td>—</td>
<td>Split System</td>
<td>6.8 HSPF</td>
</tr>
</tbody>
</table>

(continued)
### Table C403.2.3(2)—continued

**ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS**

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>HEATING SECTION TYPE</th>
<th>SUB-CATEGORY OR RATING CONDITION</th>
<th>MINIMUM EFFICIENCY</th>
<th>TEST PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooled (heating mode)</td>
<td>≥ 65,000 Btu/h and &lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>47°F db/43°F wb Outdoor Air</td>
<td>3.3 COP</td>
<td>AHRI 340/360</td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>17°F db/19°F wb Outdoor Air</td>
<td>2.25 COP</td>
<td>ISO 13256-1</td>
</tr>
<tr>
<td>Water source (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>68°F entering water</td>
<td>4.2 COP</td>
<td>ISO 13256-2</td>
</tr>
<tr>
<td>Ground water source (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>50°F entering water</td>
<td>3.6 COP</td>
<td>ISO 13256-1</td>
</tr>
<tr>
<td>Ground source (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>32°F entering fluid</td>
<td>3.1 COP</td>
<td>ISO 13256-2</td>
</tr>
<tr>
<td>Water-source water to water (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>68°F entering water</td>
<td>3.7 COP</td>
<td>ISO 13256-1</td>
</tr>
<tr>
<td>Ground source brine to water (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>50°F entering water</td>
<td>3.1 COP</td>
<td>ISO 13256-2</td>
</tr>
</tbody>
</table>

For SI: 1 British thermal unit per hour = 0.2931 W. °C = [(°F) - 32]/1.8.

a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.

b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NECA. SEER values are those set by NECA.
Minimum Efficiency Requirements: 2015 IECC

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>HEATING SECTION TYPE</th>
<th>SUBCATEGORY OR RATING CONDITION</th>
<th>MINIMUM EFFICIENCY Before 1/1/2016</th>
<th>As of 1/1/2016</th>
<th>TEST PROCEDURE</th>
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<tr>
<td>Air cooled (cooling mode)</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>13.0 SEER&lt;sup&gt;1&lt;/sup&gt;</td>
<td>14.0 SEER&lt;sup&gt;1&lt;/sup&gt;</td>
<td>AHRI 210/240</td>
</tr>
<tr>
<td>Through-the-wall, air cooled</td>
<td>≤ 30,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>12.0 SEER</td>
<td>12.0 SEER</td>
<td></td>
</tr>
<tr>
<td>Single-duct high-velocity air cooled</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>11.0 SEER</td>
<td>11.0 SEER</td>
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</tr>
<tr>
<td>Air cooled (cooling mode)</td>
<td>≥ 65,000 Btu/h and &lt; 135,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.0 EER</td>
<td>11.0 EER</td>
<td>11.2 IEER</td>
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<tr>
<td></td>
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<td>All other</td>
<td>Split System and Single Package</td>
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<td>10.8 EER</td>
<td>10.6 EER</td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h and &lt; 240,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>10.4 EER</td>
<td>10.4 EER</td>
<td>10.4 EER</td>
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<td></td>
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<td>All other</td>
<td>Split System and Single Package</td>
<td>9.5 EER</td>
<td>9.5 EER</td>
<td>9.5 EER</td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>9.3 EER</td>
<td>9.3 EER</td>
<td>9.3 EER</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>9.4 EER</td>
<td>9.4 EER</td>
<td>9.4 EER</td>
</tr>
<tr>
<td>Water to Air: Water Loop (cooling mode)</td>
<td>&lt; 17,000 Btu/h</td>
<td>All</td>
<td>80°F entering water</td>
<td>12.2 EER</td>
<td>12.2 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 17,000 Btu/h and &lt; 65,000 Btu/h</td>
<td>All</td>
<td>80°F entering water</td>
<td>13.0 EER</td>
<td>13.0 EER</td>
<td>ISO 13256-1</td>
</tr>
<tr>
<td></td>
<td>≥ 65,000 Btu/h and &lt; 135,000 Btu/h</td>
<td>All</td>
<td>80°F entering water</td>
<td>13.0 EER</td>
<td>13.0 EER</td>
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</tr>
<tr>
<td>Water to Air: Ground Water (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>59°F entering water</td>
<td>18.0 EER</td>
<td>18.0 EER</td>
<td>ISO 13256-1</td>
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<tr>
<td>Brine to Air: Ground Loop (cooling mode)</td>
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<td>All</td>
<td>77°F entering fluid</td>
<td>14.1 EER</td>
<td>14.1 EER</td>
<td>ISO 13256-1</td>
</tr>
<tr>
<td>Water to Water: Water Loop (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>80°F entering water</td>
<td>10.6 EER</td>
<td>10.6 EER</td>
<td></td>
</tr>
<tr>
<td>Water to Water: Ground Water (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>59°F entering water</td>
<td>16.3 EER</td>
<td>16.3 EER</td>
<td>ISO 13256-2</td>
</tr>
<tr>
<td>Brine to Water: Ground Loop (cooling mode)</td>
<td>&lt; 135,000 Btu/h</td>
<td>All</td>
<td>77°F entering fluid</td>
<td>12.1 EER</td>
<td>12.1 EER</td>
<td></td>
</tr>
<tr>
<td>EQUIPMENT TYPE</td>
<td>SIZE CATEGORY</td>
<td>HEATING SECTION TYPE</td>
<td>HEATING CONDITION</td>
<td>MINIMUM EFFICIENCY</td>
<td>TEST PROCEDURE</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>---------------</td>
<td>---------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>Air cooled (heating mode)</td>
<td>&lt; 65,000 Btu/h</td>
<td>—</td>
<td>Split System</td>
<td>7.7 HSPF</td>
<td>AHRI 210/240</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>Single Package</td>
<td>7.7 HSPF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Through-the-wall, (air cooled, heating mode)</td>
<td>≤ 30,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>Split System</td>
<td>7.4 HSPF</td>
<td>AHRI 340/360</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>Single Package</td>
<td>7.4 HSPF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small-duct high velocity (air cooled, heating mode)</td>
<td>&lt; 65,000 Btu/h</td>
<td>—</td>
<td>Split System</td>
<td>6.8 HSPF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air cooled (heating mode)</td>
<td>≥ 65,000 Btu/h and &lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>47°F db/43°F w.b. outdoor air</td>
<td>3.3 COP</td>
<td>ISO 13256-1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>17°F db/15°F w.b. outdoor air</td>
<td>2.25 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>47°F db/43°F w.b. outdoor air</td>
<td>3.2 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>—</td>
<td>17°F db/15°F w.b. outdoor air</td>
<td>2.05 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water to Air: Water Loop (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>68°F entering water</td>
<td>4.3 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water to Air: Ground Water (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>50°F entering water</td>
<td>3.7 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brine to Air: Ground Loop (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>32°F entering fluid</td>
<td>3.2 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water to Water: Water Loop (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>68°F entering water</td>
<td>3.7 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water to Water: Ground Water (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>50°F entering water</td>
<td>3.1 COP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brine to Water: Ground Loop (heating mode)</td>
<td>&lt; 135,000 Btu/h (cooling capacity)</td>
<td>—</td>
<td>32°F entering fluid</td>
<td>2.5 COP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For SI: 1 British thermal unit per hour = 0.2931 W. °C = [(°F) - 32] / 1.8.  
a. Chapter 6 contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.  
b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.  
For example a 5 ton cooling unit with 60 kbtu heating, an efficient SEER of 16, and an efficient HSPF of 9.5, at a restaurant in Chicago with a building permit dated after 1/1/2016 saves:

\[ \Delta kWh = [(60) * [(1/14) - (1/16)] * 1134] + [(60) * [(1/8.2) - (1/9.5)] * 1354] \]
\[ = 1963.2 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = ((kBtu/hr_{cool}) * (1/EER_{base} - 1/EER_{ee})) \times CF \]

Where CF value is chosen between:

- \( CF_{SSP} = \) Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
  
  \[ = 91.3\% \]

- \( CF_{PJM} = \) PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)
  
  \[ = 47.8\% \]

For example a 5 ton cooling unit with 60 kbtu heating, an efficient EER of 12.5 with a building permit dated after 1/1/2016 saves:

\[ \Delta kW = (60 * (1/11 - 1/12.5)) \times 0.913 \]
\[ = 0.598 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-HPSY-V05-180101**

**REVIEW DEADLINE: 1/1/2019**

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338 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

339 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
4.4.10 High Efficiency Boiler

DESCRIPTION

To qualify for this measure the installed equipment must be replacement of an existing boiler at the end of its service life, in a commercial or multifamily space with a high efficiency, gas-fired steam or hot water boiler. High efficiency boilers achieve gas savings through the utilization of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a boiler used 80% or more for space heating, not process, and boiler AFUE, TE (thermal efficiency), or Ec (combustion efficiency) rating must be rated greater than or equal to 85% for hot water boilers and 81% for steam boilers.

DEFINITION OF BASELINE EQUIPMENT

Dependent on when the unit is installed and whether the unit is hot water or steam. The baseline efficiency source is the Energy Independence and Security Act of 2007 with technical amendments from Federal Register, volume 73, Number 145, Monday, July 28, 2008 for boilers <300,000 Btu/hr and is Final Rule, Federal Register, volume 74, Number 139, Wednesday, July 22, 2009 for boiler ≥300,000 Btu/hr.

Hot water boiler baseline:

<table>
<thead>
<tr>
<th>Year</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water &lt;300,000 Btu/hr &lt; June 1, 2013</td>
<td>80% AFUE</td>
</tr>
<tr>
<td>Hot Water &lt;300,000 Btu/hr ≥ June 1, 2013</td>
<td>82% AFUE</td>
</tr>
<tr>
<td>Hot Water ≥300,000 &amp; ≤2,500,000 Btu/hr</td>
<td>80% TE</td>
</tr>
<tr>
<td>Hot Water &gt;2,500,000 Btu/hr</td>
<td>82% Ec</td>
</tr>
</tbody>
</table>

Steam boiler baseline:

<table>
<thead>
<tr>
<th>Year</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam &lt;300,000 Btu/hr &lt; June 1, 2013</td>
<td>75% AFUE</td>
</tr>
<tr>
<td>Steam &lt;300,000 Btu/hr ≥June 1, 2013</td>
<td>80% AFUE</td>
</tr>
<tr>
<td>Steam - all except natural draft ≥300,000 &amp; ≤2,500,000 Btu/hr</td>
<td>79% TE</td>
</tr>
<tr>
<td>Steam - natural draft ≥300,000 &amp; ≤2,500,000 Btu/hr</td>
<td>77% TE</td>
</tr>
<tr>
<td>Steam - all except natural draft &gt;2,500,000 Btu/hr</td>
<td>79% TE</td>
</tr>
<tr>
<td>Steam - natural draft &gt;2,500,000 Btu/hr</td>
<td>77% TE</td>
</tr>
</tbody>
</table>

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years\textsuperscript{342}

\textsuperscript{340} The Federal baseline for boilers <300,000 btu/hr changes from 80% to 82% in September 2012. To prevent a change in baseline mid-program, the increase in efficiency is delayed until June 2013 when a new program year starts.

\textsuperscript{341} Ibid.

\textsuperscript{342} The Technical support documents for federal residential appliance standards:
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf Note that this value is below the 20 years used by CA’s DEER and the range of 20-40 year estimate made by the Consortium for Energy Efficiency in 2010
DEEMED MEASURE COST

The incremental capital cost for this measure depends on efficiency as listed below:

<table>
<thead>
<tr>
<th>Measure Tier</th>
<th>Incr. Cost, per unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR® Minimum</td>
<td>$1,470</td>
</tr>
<tr>
<td>AFUE 90%</td>
<td>$2,400</td>
</tr>
<tr>
<td>AFUE 95%</td>
<td>$3,370</td>
</tr>
<tr>
<td>AFUE ≥ 96%</td>
<td>$4,340</td>
</tr>
<tr>
<td>Boilers &gt; 300,000 Btu/hr with TE (thermal efficiency) rating</td>
<td>Custom</td>
</tr>
</tbody>
</table>

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

\[ \Delta \text{Therm} = \frac{EFLH \times \text{Capacity} \times ((\text{EfficiencyRating(actual)} - \text{EfficiencyRating(base)})/\text{EfficiencyRating(base)})}{100,000} \]

Where:

- EFLH = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- Capacity = Nominal Heating Input Capacity Boiler Size (Btu/hr) for efficient unit not existing unit
- custom Boiler input capacity in Btu/hr
- EfficiencyRating(base) = Baseline Boiler Efficiency Rating, dependant on year and boiler type. Baseline efficiency values by boiler type and capacity are found in the Definition of Baseline Equipment Section
- EfficiencyRating(actual) = Efficient Boiler Efficiency Rating use actual value

<table>
<thead>
<tr>
<th>Measure Type</th>
<th>Actual AFUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR® Minimum</td>
<td>85%</td>
</tr>
</tbody>
</table>

343 Average of low and high incremental cost based on Nicor Gas program data for non-condensing and condensing boilers. Nicor Gas Energy Efficiency Plan 2011 - 2014, May 27, 2011 $1,470 for ≤ 300,000 Btu/hr for non-condensing hydronic boilers >85% AFUE & $3,365 for condensing boilers > 90% AFUE. The exception is $4,340 for AFUE ≥ 96% AFUE which was obtained from extrapolation above the size range that Nicor Gas Energy Efficiency Plan provided for incremental cost.
<table>
<thead>
<tr>
<th>Measure Type</th>
<th>Actual AFUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFUE 90%</td>
<td>90%</td>
</tr>
<tr>
<td>AFUE 95%</td>
<td>95%</td>
</tr>
<tr>
<td>AFUE ≥ 96%</td>
<td>≥ 96%</td>
</tr>
<tr>
<td>Custom</td>
<td>Value to one significant digit i.e. 95.7%</td>
</tr>
</tbody>
</table>

**EXAMPLE**

For example, a 150,000 btu/hr water boiler meeting AFUE 90% in Rockford at a high rise office building in the year 2012

\[ \Delta \text{Therm} = 2,089 \times 150,000 \times (0.90 - 0.80)/0.80 \] / 100,000 Btu/Therm

= 392 Therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BOIL-V05-150601**

**REVIEW DEADLINE: 1/1/2019**
4.4.11 High Efficiency Furnace

DESCRIPTION

This measure covers the installation of a high efficiency gas furnace in lieu of a standard efficiency gas furnace in a commercial or industrial space. High efficiency gas furnaces achieve savings through the utilization of a sealed, super insulated combustion chamber, more efficient burners, and multiple heat exchangers that remove a significant portion of the waste heat from the flue gases. Because multiple heat exchangers are used to remove waste heat from the escaping flue gases, most of the flue gases condense and must be drained. Furnaces equipped with ECM fan motors can save additional electric energy.

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

Time of sale:

a. The installation of a new high efficiency, gas-fired condensing furnace in a commercial location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system.

Early replacement:

Early Replacement determination will be based on meeting the following conditions:

• The existing unit is operational when replaced, or
• The existing unit requires minor repairs (<$528)\(^\text{344}\).
• All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

• If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
• If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
• If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed equipment must be a furnace with input energy less than 225,000 Btu/hr rated natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating and fan electrical efficiency exceeding the program requirements:

DEFINITION OF BASELINE EQUIPMENT

Time of Sale: Although the current Federal Standard for gas furnaces is an AFUE rating of 78%, based upon review of available product in the AHRI database, the baseline efficiency for this characterization is assumed to be 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. As discussed above we estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

\(^{344}\) The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.
DEFINITION OF MEASURE LIFE

The expected measure life is assumed to be 16.5 years\textsuperscript{345}.

Remaining life of existing equipment is assumed to be 5.5 years\textsuperscript{346}.

DEEMED MEASURE COST

Time of Sale: The incremental capital cost for this measure depends on efficiency as listed below\textsuperscript{347}:

<table>
<thead>
<tr>
<th>AFUE</th>
<th>Installation Cost</th>
<th>Incremental Install Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>$2011</td>
<td>n/a</td>
</tr>
<tr>
<td>90%</td>
<td>$2641</td>
<td>$630</td>
</tr>
<tr>
<td>91%</td>
<td>$2727</td>
<td>$716</td>
</tr>
<tr>
<td>92%</td>
<td>$2813</td>
<td>$802</td>
</tr>
<tr>
<td>93%</td>
<td>$3049</td>
<td>$1,038</td>
</tr>
<tr>
<td>94%</td>
<td>$3286</td>
<td>$1,275</td>
</tr>
<tr>
<td>95%</td>
<td>$3522</td>
<td>$1,511</td>
</tr>
<tr>
<td>96%</td>
<td>$3758</td>
<td>$1,747</td>
</tr>
</tbody>
</table>

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 5.5 years) of replacing existing equipment with a new baseline unit is assumed to be $2876\textsuperscript{348}. This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta k\text{Wh} = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings} \]

Where:

Heating Savings = Brushless DC motor or Electronically commutated motor (ECM) = 418 kWh\textsuperscript{349}

\textsuperscript{345} Average of 15-18 year lifetime estimate made by the Consortium for Energy Efficiency in 2010.

\textsuperscript{346} Assumed to be one third of effective useful life.

\textsuperscript{347} Based on data from Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are.

\textsuperscript{348} $2641 inflated using 1.91\% rate.

\textsuperscript{349} To estimate heating, cooling and shoulder season savings for Illinois, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: FOE to IL Blower Savings.xlsx.
Cooling Savings = Brushless DC motor or electronically commutated motor (ECM) savings during cooling season
If air conditioning = 263 kWh
If no air conditioning = 175 kWh
If unknown (weighted average) = 241 kWh

Shoulder Season Savings = Brushless DC motor or electronically commutated motor (ECM) savings during shoulder seasons
= 51 kWh

**EXAMPLE**
For example, a blower motor in a low rise office building where air conditioning presence is unknown:

\[ \Delta \text{kWh} = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings} \]
\[ = 418 + 241 + 51 \]
\[ = 710 \text{kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**
For units that have evaporator coils and condensing units and are cooling in the summer in addition to heating in the winter the summer coincident peak demand savings should be calculated. If the unit is not equipment with coils or condensing units, the summer peak demand savings will not apply.

\[ \Delta \text{kW} = \left( \frac{\text{CoolingSavings}}{\text{HOURSyear}} \right) \times \text{CF} \]

Where:

HOURSyear = Actual hours per year if known, otherwise use hours from Table below for building type\(^{351}\).
Building Type | HOURS\text{year}
--- | ---
MF - High Rise | 4237
MF - Mid Rise | 2899
Hotel/Motel - Guest | 4479
Hotel/Motel - Common | 8712
Movie Theater | 2120
Office - High Rise - VAV econ | 2038
Office - High Rise - CAV econ | 4849
Office - High Rise - CAV no econ | 5682
Office - High Rise - FCU | 3069
Office - Low Rise | 2481
Office - Mid Rise | 1881
Religious Building | 2830
Restaurant | 3350
Retail - Department Store | 2528
Retail - Strip Mall | 2266
Warehouse | 770
Unknown | 2718

\text{CF} = \text{Summer Peak Coincidence Factor for measure is provided below for different building types}^{352}:

<table>
<thead>
<tr>
<th>HVAC Pumps</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>48.3%</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>52.9%</td>
</tr>
<tr>
<td>College</td>
<td>14.2%</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>57.1%</td>
</tr>
<tr>
<td>Elementary School</td>
<td>33.3%</td>
</tr>
<tr>
<td>Garage</td>
<td>61.9%</td>
</tr>
<tr>
<td>Grocery</td>
<td>47.5%</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>61.9%</td>
</tr>
<tr>
<td>High School</td>
<td>28.8%</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td>57.6%</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>61.5%</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>64.8%</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>60.9%</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>43.3%</td>
</tr>
<tr>
<td>MF - High Rise - Common</td>
<td>43.7%</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>24.3%</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>62.9%</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>64.6%</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>41.9%</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>43.2%</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td>48.3%</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td>50.3%</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td>46.2%</td>
</tr>
</tbody>
</table>

\textsuperscript{352} Coincidence Factors are estimated using the eQuest models.
### HVAC Pumps

<table>
<thead>
<tr>
<th></th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office - Low Rise</td>
<td>47.4%</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>42.8%</td>
</tr>
<tr>
<td>Religious Building</td>
<td>43.3%</td>
</tr>
<tr>
<td>Restaurant</td>
<td>48.8%</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>50.5%</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>52.8%</td>
</tr>
<tr>
<td>Warehouse</td>
<td>22.5%</td>
</tr>
<tr>
<td>Unknown</td>
<td>42.4%</td>
</tr>
</tbody>
</table>

### Natural Gas Energy Savings

**Time of Sale:**

\[
\Delta \text{Therms} = EFLH \times \text{Capacity} \times \left( \frac{(\text{AFUE}(\text{eff}) - \text{AFUE}(\text{base}))}{\text{AFUE}(\text{base})} \right) / 100,000 \text{ Btu/Therm}
\]

**Early replacement**:

\[
\Delta \text{Therms} \text{ for remaining life of existing unit (1st 5.5 years)}:
\]

\[
\Delta \text{Therms} = EFLH \times \text{Capacity} \times \left( \frac{(\text{AFUE}(\text{eff}) - \text{AFUE}(\text{exist}))}{\text{AFUE}(\text{exist})} \right) / 100,000 \text{ Btu/Therm}
\]

**ΔTherms for remaining measure life (next 11 years):**

\[
\Delta \text{Therms} = EFLH \times \text{Capacity} \times \left( \frac{(\text{AFUE}(\text{eff}) - \text{AFUE}(\text{base}))}{\text{AFUE}(\text{base})} \right) / 100,000 \text{ Btu/Therm}
\]

Where:

- **EFLH** = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
- **Capacity** = Nominal Heating Input Capacity Furnace Size (Btu/hr) for efficient unit not existing unit
  - = custom Furnace input capacity in Btu/hr
- **AFUE(exist)** = Existing Furnace Annual Fuel Utilization Efficiency Rating
  - = Use actual AFUE rating where it is possible to measure or reasonably estimate.
  - If unknown, assume 64.4 AFUE%  \(^{354}\).
- **AFUE(base)** = Baseline Furnace Annual Fuel Utilization Efficiency Rating, dependant on year as listed below:

---

\(^{353}\) 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).

\(^{354}\) Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
Dependent on program type as listed below:\(^{355}\):

<table>
<thead>
<tr>
<th>Program Year</th>
<th>AFUE(base)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>80%</td>
</tr>
<tr>
<td>Early Replacement</td>
<td>90%</td>
</tr>
</tbody>
</table>

AFUE(eff) = Efficient Furnace Annual Fuel Utilization Efficiency Rating.
= Actual. If Unknown, assume 95%\(^{356}\)

**EXAMPLE**

\[
\Delta\text{Therms} = 1428 \times 150,000 \times \left(\frac{(0.92 - 0.80)}{0.80}\right) / 100,000
\]

\[
= 321 \text{ Therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-FRNC-V07-180101**

**REVIEW DEADLINE: 1/1/2019**

\(^{355}\) Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

\(^{356}\) Minimum ENERGY STAR efficiency after 2.1.2012.
4.4.12 Infrared Heaters (all sizes), Low Intensity

**DESCRIPTION**

This measure applies to natural gas fired low-intensity infrared heaters with an electric ignition that use non-conditioned air for combustion.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a natural gas heater with an electric ignition that uses non-conditioned air for combustion.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a standard natural gas fired heater warm air heater.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years.\textsuperscript{357}

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $1716.\textsuperscript{358}

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

The annual natural gas energy savings from this measure is a deemed value equaling 451 Therms.\textsuperscript{359}

\textsuperscript{357}ENERGY STAR and CEE do not currently provide calculators for this type of equipment therefore deemed values from Nicor Gas were used. Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011

\textsuperscript{358}Ibid.

\textsuperscript{359}Nicor Gas Energy Efficiency Plan 2011-2014. Revised Plan Filed Pursuant to Order Docket 10-0562, May 27, 2011. These deemed values should be compared to PY evaluation and revised as necessary.
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-IRHT-V01-120601

REVIEW DEADLINE: 1/1/2019
4.4.13 Package Terminal Air Conditioner (PTAC) and Package Terminal Heat Pump (PTHP)

**DESCRIPTION**

A PTAC is a packaged terminal air conditioner that cools and sometimes provides heat through an electric resistance heater (heat strip). A PTHP is a packaged terminal heat pump. A PTHP uses its compressor year round to heat or cool. In warm weather, it efficiently captures heat from inside your building and pumps it outside for cooling. In cool weather, it captures heat from outdoor air and pumps it into your home, adding heat from electric heat strips as necessary to provide heat.

This measure characterizes:

a) Time of Sale: the purchase and installation of a new efficient PTAC or PTHP.
b) Early Replacement: the early removal of an existing PTAC or PTHP from service, prior to its natural end of life, and replacement with a new efficient PTAC or PTHP unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life. The measure is only valid for non-fuel switching installations – for example replacing a cooling only PTAC with a PTHP can currently not use the TRM.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to be PTACs or PTHPs that exceed baseline efficiencies.

**DEFINITION OF BASELINE EQUIPMENT**

Time of Sale: the baseline conditions is provided in the Federal Baseline reference table provided below.

Early Replacement: the baseline is the existing PTAC or PTHP for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 years.\(^\text{360}\)

Remaining life of existing equipment is assumed to be 5 years.\(^\text{361}\)

**DEEMED MEASURE COST**

Time of Sale: The incremental capital cost for this equipment is estimated to be $84/ton.\(^\text{362}\)

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unknown assume $1,047 per ton.\(^\text{363}\).

The assumed deferred cost (after 5 years) of replacing existing equipment with new baseline unit is assumed to be $1,039 per ton.\(^\text{364}\). This cost should be discounted to present value using the nominal discount rate.

---


\(^{361}\) Standard assumption of one third of effective useful life.

\(^{362}\) DEER 2008. This assumes that baseline shift from IECC 2012 to IECC 2015 carries the same incremental costs. Values should be verified during evaluation.

\(^{363}\) Based on DCEO – IL PHA Efficient Living Program data.

\(^{364}\) Based on subtracting TOS incremental cost from the DCEO data and incorporating inflation rate of 1.91%.
LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

\[ \text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} = 91.3\% \]

\[ \text{CF}_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} = 47.8\% \]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Electric savings for PTACs and PTHPs should be calculated using the following algorithms

ENERGY SAVINGS

Time of Sale:

\[ \text{PTAC } \Delta\text{kWh}^{367} = \text{Annual kWh Savings}_{\text{cool}} \]

\[ \text{PTHP } \Delta\text{kWh} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}} \]

\[ \text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) \times \left( \frac{1}{\text{EERbase}} - \frac{1}{\text{EERee}} \right) \times \text{EFLH}_{\text{cool}} \]

\[ \text{Annual kWh Savings}_{\text{heat}} = \left( \frac{\text{kBtu/hr}_{\text{heat}}}{3.412} \right) \times \left( \frac{1}{\text{COPbase}} - \frac{1}{\text{COPee}} \right) \times \text{EFLH}_{\text{heat}} \]

Early Replacement:

\[ \Delta\text{kWh for remaining life of existing unit (1st 5 years)} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}} \]

\[ \text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) \times \left( \frac{1}{\text{EERexist}} - \frac{1}{\text{EERee}} \right) \times \text{EFLH}_{\text{cool}} \]

\[ \text{Annual kWh Savings}_{\text{heat}} = \left( \frac{\text{kBtu/hr}_{\text{heat}}}{3.412} \right) \times \left( \frac{1}{\text{COPexist}} - \frac{1}{\text{COPee}} \right) \times \text{EFLH}_{\text{heat}} \]

\[ \Delta\text{kWh for remaining measure life (next 10 years)} = \text{Annual kWh Savings}_{\text{cool}} + \text{Annual kWh Savings}_{\text{heat}} \]

\[ \text{Annual kWh Savings}_{\text{cool}} = (\text{kBtu/hr}_{\text{cool}}) \times \left( \frac{1}{\text{EERbase}} - \frac{1}{\text{EERee}} \right) \times \text{EFLH}_{\text{cool}} \]

\[ \text{Annual kWh Savings}_{\text{heat}} = \left( \frac{\text{kBtu/hr}_{\text{heat}}}{3.412} \right) \times \left( \frac{1}{\text{COPbase}} - \frac{1}{\text{COPee}} \right) \times \text{EFLH}_{\text{heat}} \]

Where:

\[ ^{365} \text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.} \]

\[ ^{366} \text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year} \]

\[ ^{367} \text{There are no heating efficiency improvements for PTACs since although some do provide heating, it is always through electric resistance and therefore the COPbase and COPee would be 1.0.} \]
kBtu/hr_{cool} = capacity of the cooling equipment in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr).

= Actual installed

EFLH_{cool} = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use:

EFLH_{heat} = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

EER_{exist} = Energy Efficiency Ratio of the existing equipment

= Actual. If unknown assume 8.1 EER_{368}

EER_{base} = Energy Efficiency Ratio of the baseline equipment; see the table below for values.

= Based on applicable IECC code on date of building permit (if unknown assume IECC 2015).

EER_{ree} = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EER_{ree} is unknown, assume the following conversion from SEER to EER for calculation of peak savings_{369}: EER = (0.02 * SEER) + (1.12 * SEER)

kBtu/hr_{heat} = capacity of the heating equipment in kBtu per hour.

= Actual installed

---

**Copy of Table C403.2.3(3): Minimum Efficiency Requirements: Electrically operated packaged terminal air conditioners, packaged terminal heat pumps**

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>IECC 2012 Minimum Efficiency</th>
<th>IECC 2015 Minimum Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTAC (Cooling mode)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Construction</td>
<td>13.8 – (0.300 x Cap/1000) EER</td>
<td>14.0 – (0.300 x Cap/1000) EER</td>
</tr>
<tr>
<td>Replacements</td>
<td>10.9 – (0.213 x Cap/1000) EER</td>
<td>10.9 – (0.213 x Cap/1000) EER</td>
</tr>
<tr>
<td>PTHP (Cooling mode)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Construction</td>
<td>14.0 – (0.300 x Cap/1000) EER</td>
<td>14.0 – (0.300 x Cap/1000) EER</td>
</tr>
<tr>
<td>Replacements</td>
<td>10.8 – (0.213 x Cap/1000) EER</td>
<td>10.8 – (0.213 x Cap/1000) EER</td>
</tr>
<tr>
<td>PTHP (Heating mode)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Construction</td>
<td>3.2 – (0.026 x Cap/1000) COP</td>
<td>3.2 – (0.026 x Cap/1000) COP</td>
</tr>
<tr>
<td>Replacements</td>
<td>2.9 – (0.026 x Cap/1000) COP</td>
<td>2.9 – (0.026 x Cap/1000) COP</td>
</tr>
</tbody>
</table>

“Cap” = The rated cooling capacity of the project in Btu/hr. If the units capacity is less than 7000 Btu/hr, use 7,000 Btu/hr in the calculation. If the unit’s capacity is greater than 15,000 Btu/hr, use 15,000 Btu/hr in the calculations.

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 (406mm) in height and less than 42 inches (1067 mm) in width.

EER_{ree} = Energy Efficiency Ratio of the energy efficient equipment. For air-cooled units < 65 kBtu/hr, if the actual EER_{ree} is unknown, assume the following conversion from SEER to EER for calculation of peak savings_{369}: EER = (0.02 * SEER) + (1.12 * SEER)

kBtu/hr_{heat} = capacity of the heating equipment in kBtu per hour.

= Actual installed

---

_{368} Estimated using the IECC building energy code up until year 2003 (p107; https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf) and assuming a 1 ton unit; EER = 10 – (0.16 * 12,000/1,000) = 8.1.

3.412 = Btu per Wh.
COPexist = coefficient of performance of the existing equipment
          = Actual. If unknown assume 1.0 COP for PTAC units and 2.6 COP\(^{370}\) for PTHPs.
COPbase = coefficient of performance of the baseline equipment; see table above for values.
COPee = coefficient of performance of the energy efficient equipment.
          = Actual installed

**EXAMPLE:**

Time of Sale (assuming new construction baseline):
For example a 1 ton PTAC with an efficient EER of 12 at a guest hotel in Rockford with a building permit dated before 1/1/2016 saves:

\[
\Delta kW = (12) * [(1/10.2) – (1/12)] * 1,042
\]
\[
= 184 \text{ kWh}
\]

Early Replacement (assuming replacement baseline for deferred replacement in 5 years):
For example a 1 ton PTHP with an efficient EER of 12, COP of 3.0 at a guest hotel in Rockford replaces a PTAC unit (with electric resistance heat) with unknown efficiency.

\[
\Delta kW \text{ for remaining life of existing unit (1st 5 years)} = (12 * (1/8.1 – 1/12) * 1,042) + (12/3.412 * (1/1.0 – 1/3.0) * 1,758)
\]
\[
= 502 + 4,122
\]
\[
= 4,624 \text{ kWh}
\]

\[
\Delta kW \text{ for remaining measure life (next 10 years)} = (12 * (1/8.3 – 1/12) * 1,042) + (12/3.412 * (1/1.0 – 1/3.0) * 1,758)
\]
\[
= 465 + 4,122
\]
\[
= 34,587 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of Sale:
\[
\Delta kW = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * CF
\]

Early Replacement:
\[
\Delta kW \text{ for remaining life of existing unit (1st 5 years)} = (kBtu/hr_{cool}) * [(1/EERexist) – (1/EERee)] * CF
\]
\[
\Delta kW \text{ for remaining measure life (next 10 years)} = (kBtu/hr_{cool}) * [(1/EERbase) – (1/EERee)] * CF
\]

Where:
CF\(_{SSP}\) = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

\(^{370}\)Estimated using the IECC building energy code up until year 2003 (p107; https://law.resource.org/pub/us/code/ibr/icc.iecc.2000.pdf) and assuming a 1 ton unit; COP = 2.9 – (0.026 * 12,000/1,000) = 2.6
\[ \text{CF}_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \]
\[ \text{NATURAL GAS ENERGY SAVINGS} \]
N/A

\[ \text{WATER IMPACT DESCRIPTIONS AND CALCULATION} \]
N/A

\[ \text{DEEMED O&M COST ADJUSTMENT CALCULATION} \]
N/A

\[ \text{MEASURE CODE: CI-HVC-PTAC-V08-180101} \]

\[ \text{REVIEW DEADLINE: 1/1/2020} \]

---

\[ \text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.} \]

\[ \text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.} \]
**4.4.14 Pipe Insulation**

**DESCRIPTION**

This measure provides rebates for installation of ≥1” or ≥2” fiberglass, foam, calcium silicate or other types of insulation with similar insulating properties to existing bare pipe on straight piping as well as other pipe components such as elbows, tees, valves, and flanges for all non-residential installations.

Default per linear foot savings estimates are provided for the both exposed indoor or above ground outdoor piping distributing fluid in the following system types (natural gas fired systems only):

- Hydronic heating systems (with or without outdoor reset controls), including:
  - boiler systems that do not circulate water around a central loop and operate upon demand from a thermostat ("non-recirculation")
  - systems that recirculate during heating season only ("Recirculation – heating season only")
  - systems recirculating year round ("Recirculation – year round")

- Domestic hot water

- Low and high-pressure steam systems
  - non-recirculation
  - recirculation - heating season only
  - recirculation - year round

Process piping can also use the algorithms provided but requires custom entry of hours.

Minimum qualifying nominal pipe diameter is 1.” Indoor piping must have at least 1” of insulation and outdoor piping must have at least 2” of insulation and include an all-weather protective jacket. New advanced insulating materials may be thinner and savings can be calculated with 3E Plus.

This measure was developed to be applicable to the following program types: RF, DI

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient case is installing pipe wrap insulation to a length of pipe. Indoor piping must have at least 1” of insulation (or equivalent R-value) and outdoor piping must have at least 2” of insulation (or equivalent R-value) and include an all-weather protective jacket. Minimum qualifying pipe diameter is 1.” Insulation must be continuous and contiguous over fittings that directly connect to straight pipe, including elbows and tees.\(^{373}\)

**DEFINITION OF BASELINE EQUIPMENT**

The base case for savings estimates is a bare pipe. Pipes are required by new construction code to be insulated but are still commonly found uninsulated in older commercial buildings.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 15 years.\(^{374}\)

---


DEEMED MEASURE COST

Actual costs should be used if known. Otherwise the deemed measure costs below based on RS Means\textsuperscript{375} pricing reference materials may be used.\textsuperscript{376} The following table summarizes the estimated costs for this measure per foot of insulation added and include installation costs:

<table>
<thead>
<tr>
<th>Insulation Thickness</th>
<th>1 Inch (Indoor)</th>
<th>2 Inches (Outdoor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pipe- RS Means #</td>
<td>220719.10.5170</td>
<td>220719.10.5530</td>
</tr>
<tr>
<td>Jacket- RS Means #</td>
<td>220719.10.0156</td>
<td>220719.10.0320</td>
</tr>
<tr>
<td>Jacket Type</td>
<td>PVC</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Insulation Cost per foot</td>
<td>$9.40</td>
<td>$13.90</td>
</tr>
<tr>
<td>Jacket Cost per foot</td>
<td>$4.57</td>
<td>$7.30</td>
</tr>
<tr>
<td>Total Cost per foot</td>
<td>$13.97</td>
<td>$21.20</td>
</tr>
</tbody>
</table>

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

\[
\Delta \text{therms per foot}\textsuperscript{377} = \left[\left(\frac{Q_{\text{base}} - Q_{\text{eff}}}{100,000 \times \eta_{\text{Boiler}}}\right) \times \text{TRF}\right] \\
\Delta \text{therms} = (L_{\text{sp}} + L_{\text{oc}}) \times \Delta \text{therms per foot}
\]

Where:

- EFLH = Equivalent Full Load Hours for Heating
- Actual or defaults by building type provided in Section 4.4, HVAC end use
- For year round recirculation or domestic hot water:
  \[= 8,766\]

For heating season recirculation, hours with the outside air temperature below 55°F:

\textsuperscript{375} RS Means 2008. Mechanical Cost Data, pages 106 to 119
\textsuperscript{376} RS Means 2010: “for fittings, add 3 linear feet for each fitting plus 4 linear feet for each flange of the fitting”
\textsuperscript{377} This value comes from the reference table “Savings Summary by Building Type and System Type.” The formula and the input tables in this section document assumptions used in calculation spreadsheet “Pipe Insulation Savings 2013-11-12.xlsx”
## 4.4.14 Pipe Insulation

<table>
<thead>
<tr>
<th>Zone</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 (Rockford)</td>
<td>5,039</td>
</tr>
<tr>
<td>Zone 2 (Chicago)</td>
<td>4,963</td>
</tr>
<tr>
<td>Zone 3 (Springfield)</td>
<td>4,495</td>
</tr>
<tr>
<td>Zone 4 (Belleville)</td>
<td>4,021</td>
</tr>
<tr>
<td>Zone 5 (Marion)</td>
<td>4,150</td>
</tr>
<tr>
<td>Zone 1 (Rockford)</td>
<td>5,039</td>
</tr>
</tbody>
</table>

**Zone Hours**

- Zone 1 (Rockford): 5,039 hours
- Zone 2 (Chicago): 4,963 hours
- Zone 3 (Springfield): 4,495 hours
- Zone 4 (Belleville): 4,021 hours
- Zone 5 (Marion): 4,150 hours
- Zone 1 (Rockford): 5,039 hours

**Q_{base}**

- Heat Loss from Bare Pipe (Btu/hr/ft)
- Calculated where possible using 3E Plusv4.0 software. For defaults see table below

**Q_{eff}**

- Heat Loss from Insulated Pipe (Btu/hr/ft)
- Calculated where possible using 3E Plusv4.0 software. For defaults see table below

100,000

- Conversion factor (1 therm = 100,000 Btu)

**η_{Boiler}**

- Efficiency of the boiler being used to generate the hot water or steam in the pipe
- Actual or if unknown use default values given below:
  - 81.9% for water boilers
  - 80.7% for steam boilers, except multifamily low-pressure
  - 64.8% for multifamily low-pressure steam boilers

**TRF**

- Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below
- See table below for base TRF values by pipe location

May vary seasonally such as: TRF[summer] * summer hours + TRF[winter] * winter hours where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature.

<table>
<thead>
<tr>
<th>Pipe Location</th>
<th>Assumed Regain</th>
<th>TRF, Thermal Regain Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor</td>
<td>0%</td>
<td>1.0</td>
</tr>
<tr>
<td>Indoor, heated space</td>
<td>85%</td>
<td>0.15</td>
</tr>
<tr>
<td>Indoor, semi-heated, (unconditioned space, with heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall)</td>
<td>30%</td>
<td>0.70</td>
</tr>
</tbody>
</table>

---

378 Average efficiencies of units from the California Energy Commission (CEC).
379 Ibid.
381 Thermal regain for **residential** pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation.
382 Thermal Regain Factor_4-30-14.docx
### Pipe Insulation

<table>
<thead>
<tr>
<th>Pipe Location</th>
<th>Assumed Regain</th>
<th>TRF, Thermal Regain Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor, unheated, (no heat transfer to conditioned space)</td>
<td>0%</td>
<td>1.0</td>
</tr>
<tr>
<td>Location not specified</td>
<td>85%</td>
<td>0.15</td>
</tr>
<tr>
<td>Custom</td>
<td>Custom</td>
<td>1 – assumed regain</td>
</tr>
</tbody>
</table>

$L_{sp}$ = Length of straight pipe to be insulated (linear foot)

$L_{loc,I}$ = Total equivalent length of the other components (valves and tees) of pipe to be insulated

= Actual installed (linear foot). See table “Equivalent Length of Other Components – Elbows and Tees” for equivalent lengths.

The heat loss estimates ($Q_{base}$ and $Q_{eff}$) were developed using the 3E Plus v4.0 software program. The energy savings analysis is based on adding 1-inch (indoor) or 2-inch (outdoor) thick insulation around bare pipe. The thermal conductivity of pipe insulation varies by material and temperature rating; to obtain a typical value, a range of materials allowed for this measure were averaged. For insulation materials not in the table below, use 3E Plusv4.0 software to calculate $Q_{base}$ and $Q_{eff}$.

<table>
<thead>
<tr>
<th>Insulation Type</th>
<th>Conductivity (Btu.in / hr.ft².ºF @ 75ºF)</th>
<th>Max temp (ºF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene foam</td>
<td>0.25</td>
<td>200</td>
</tr>
<tr>
<td>Flexible polyurethane-based foam</td>
<td>0.27</td>
<td>200</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>0.31</td>
<td>250</td>
</tr>
<tr>
<td>Melamine foam</td>
<td>0.26</td>
<td>350</td>
</tr>
<tr>
<td>Flexible silicon foam</td>
<td>0.40</td>
<td>392</td>
</tr>
<tr>
<td>Calcium silicate</td>
<td>0.40</td>
<td>1200</td>
</tr>
<tr>
<td>Cellular glass</td>
<td>0.31</td>
<td>400</td>
</tr>
<tr>
<td>Average conductivity of all these materials (Btu.in / hr.ft².ºF @ 75ºF)</td>
<td>0.31</td>
<td></td>
</tr>
</tbody>
</table>

The pipe fluid temperature assumption used depends upon both the system type and whether there is outdoor reset controls:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Fluid temperature assumption (ºF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water space heating with outdoor reset - Non recirculation</td>
<td>145</td>
</tr>
<tr>
<td>Hot Water space heating without outdoor reset - Non recirculation</td>
<td>170</td>
</tr>
<tr>
<td>Hot Water space heating with outdoor reset – Recirculation heating season only</td>
<td>145</td>
</tr>
<tr>
<td>Hot Water space heating without outdoor reset – Recirculation heating season only</td>
<td>170</td>
</tr>
<tr>
<td>Hot Water space heating with outdoor reset – Recirculation year round</td>
<td>130</td>
</tr>
<tr>
<td>Hot Water space heating without outdoor reset – Recirculation year round</td>
<td>170</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>125</td>
</tr>
<tr>
<td>Low Pressure Steam</td>
<td>225</td>
</tr>
<tr>
<td>High Pressure Steam</td>
<td>312</td>
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</tbody>
</table>

3E Plus is a heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association).
## Pipe Insulation

### Insulation thickness (inch)
<table>
<thead>
<tr>
<th>Indoor Insulation, Hot Water</th>
<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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### Temperature, Fluid in Pipe (°F)

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<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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</thead>
<tbody>
<tr>
<td>170 (w/o reset)</td>
<td>145 (w/ reset heat)</td>
<td>130 (w/ reset year)</td>
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<td>1</td>
<td>170 (w/o reset)</td>
<td>145 (w/ reset heat)</td>
</tr>
<tr>
<td>225</td>
<td>312</td>
<td>125</td>
<td></td>
<td></td>
<td>225</td>
<td>312</td>
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</tbody>
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### Av. steam pressure (psig)

<table>
<thead>
<tr>
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<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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<tbody>
<tr>
<td>n/a</td>
<td>10.9</td>
<td>82.8</td>
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### Operating Time (hrs/yr)

<table>
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<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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</thead>
<tbody>
<tr>
<td>2,746 (non-recirc)</td>
<td>5,039 (recirc heating season)</td>
<td>8,760 (recirc year round)</td>
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### Ambient Temperature (°F)

<table>
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<tr>
<th>Indoor Insulation, Hot Water</th>
<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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<tr>
<td>75</td>
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<td>75</td>
<td>48.6</td>
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<td>48.6</td>
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### Wind speed (mph)

<table>
<thead>
<tr>
<th>Indoor Insulation, Hot Water</th>
<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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<tbody>
<tr>
<td>385</td>
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<td>0</td>
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### Pipe parameters

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<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
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</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Steel</td>
<td>Steel</td>
<td>Copper</td>
<td>Copper</td>
<td>Steel</td>
<td>Steel</td>
</tr>
<tr>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
<td>2&quot;</td>
</tr>
<tr>
<td>Outer Diameter, actual</td>
<td>2.38&quot;</td>
<td>2.38&quot;</td>
<td>2.38&quot;</td>
<td>2.38&quot;</td>
<td>2.38&quot;</td>
<td>2.38&quot;</td>
</tr>
<tr>
<td>Heat Loss, Bare Pipe (from 3EPlus) (Btu/hr.ft)</td>
<td>114 (w/o reset)</td>
<td>78 (w/ reset heat)</td>
<td>58 (w/ reset year)</td>
<td>232</td>
<td>432</td>
<td>52</td>
</tr>
<tr>
<td>Average Heat Loss, Insulation (from 3EPlus) (Btu/hr.ft)</td>
<td>24 (w/o reset)</td>
<td>17 (w/ reset heat)</td>
<td>13 (w/ reset year)</td>
<td>40</td>
<td>70</td>
<td>13.25</td>
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</table>

### Annual Energy Savings

<table>
<thead>
<tr>
<th>Indoor Insulation, Hot Water</th>
<th>Indoor Insulation, Low Pressure Steam</th>
<th>Indoor Insulation, High Pressure Steam</th>
<th>Domestic Hot Water</th>
<th>Outdoor Insulation, Hot Water</th>
<th>Outdoor Insulation, Low Pressure Steam</th>
<th>Outdoor Insulation, High Pressure Steam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler / Water Heater efficiency</td>
<td>81.9%</td>
<td>80.7% (64.8% for MF)</td>
<td>80.7%</td>
<td>67%</td>
<td>81.9%</td>
<td>80.7%</td>
</tr>
<tr>
<td>Annual Gas Use, Base Case (therms/yr)</td>
<td>3.8 (w/o reset)</td>
<td>4.8 (w/ reset heat)</td>
<td>6.2 (w/ reset year)</td>
<td>7.9 (non recirc)</td>
<td>14.5 (recirc heat)</td>
<td>25.2 (recirc year)</td>
</tr>
<tr>
<td>Annual Gas Use, Measure case (therms/yr)</td>
<td>0.8 (w/o reset)</td>
<td>1.1 (w/ reset heat)</td>
<td>1.4 (w/ reset year)</td>
<td>1.4 (non recirc)</td>
<td>2.5 (recirc heat)</td>
<td>4.4 (recirc year)</td>
</tr>
<tr>
<td>Annual Gas Savings (therms/yr)</td>
<td>3.0 (w/o reset)</td>
<td>3.7 (w/ reset heat)</td>
<td>4.8 (w/ reset year)</td>
<td>6.5 (non recirc)</td>
<td>12.0 (recirc heat)</td>
<td>20.8 (recirc year)</td>
</tr>
</tbody>
</table>

Heat = heating season only, year = year round

---

**Notes:**

- 384 DOE Weather Data.
- 385 Ibid.

**References:**

2. Ibid.
Values below must be multiplied by the appropriate Thermal Regain Factor (TRF). All variables were the same except for hours of operation in the calculation of the default savings per foot for the various building types and applications as presented in the table below:

**Savings Summary for Indoor pipe insulation by System Type and Building Type (Δtherms per foot)**
(continues for 3.5 pages)

<table>
<thead>
<tr>
<th>Location</th>
<th>System Type</th>
<th>Building Type</th>
<th>Zone 1 (Rockford)</th>
<th>Zone 2 (Chicago)</th>
<th>Zone 3 (Springfield)</th>
<th>Zone 4 (Belleville)</th>
<th>Zone 5 (Marion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor</td>
<td>Hot Water Space</td>
<td>Heating with</td>
<td>Assembly</td>
<td>1.32</td>
<td>1.36</td>
<td>1.21</td>
<td>0.81</td>
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<tr>
<td></td>
<td></td>
<td>outdoor reset –</td>
<td>Assisted Living</td>
<td>1.25</td>
<td>1.22</td>
<td>1.07</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td></td>
<td>non-recirculation</td>
<td>College</td>
<td>1.13</td>
<td>1.06</td>
<td>0.95</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Convenience Store</td>
<td>1.10</td>
<td>1.01</td>
<td>0.90</td>
<td>0.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Elementary School</td>
<td>1.32</td>
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<td>1.13</td>
<td>0.78</td>
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<td>1.04</td>
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<td></td>
<td>Healthcare Clinic</td>
<td>1.17</td>
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<td>1.05</td>
<td>0.71</td>
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<td>1.31</td>
<td>1.35</td>
<td>1.15</td>
<td>0.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hospital - CAV econ</td>
<td>1.33</td>
<td>1.37</td>
<td>1.17</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
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<td>Hospital - VAV econ</td>
<td>0.54</td>
<td>0.51</td>
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<tr>
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<td>Hospital - FCU</td>
<td>0.98</td>
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<td>0.91</td>
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<td></td>
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<td>Hotel/Motel</td>
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<td>1.14</td>
<td>0.78</td>
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<td></td>
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<td></td>
<td>Hotel/Motel - Common</td>
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<td>1.21</td>
<td>1.15</td>
<td>0.93</td>
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<td>0.79</td>
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<td>0.93</td>
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<td>Assembly</td>
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<td>1.90</td>
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</table>
### Annual Therm Savings per Linear Foot (therm/ft)

(2" pipe / 1" insulation for hot water, 2" insulation for steam)

<table>
<thead>
<tr>
<th>Location</th>
<th>System Type</th>
<th>Building Type</th>
<th>Zone 1 (Rockford)</th>
<th>Zone 2 (Chicago)</th>
<th>Zone 3 (Springfield)</th>
<th>Zone 4 (Belleville)</th>
<th>Zone 5 (Marion)</th>
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<tbody>
<tr>
<td>Grocery</td>
<td></td>
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<td>1.76</td>
<td>1.75</td>
<td>1.54</td>
<td>0.96</td>
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<tr>
<td>Healthcare Clinic</td>
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<td>1.77</td>
<td>1.55</td>
<td>1.05</td>
<td>1.11</td>
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<td>2.03</td>
<td>1.82</td>
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<td>1.99</td>
<td>1.69</td>
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<td>2.03</td>
<td>1.73</td>
<td>1.50</td>
<td>1.70</td>
</tr>
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<td>0.37</td>
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<td>1.58</td>
<td>2.13</td>
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<tr>
<td>Hotel/Motel</td>
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<td>Hotel/Motel - Guest</td>
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<td>1.11</td>
<td>1.37</td>
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<tr>
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<td>1.15</td>
<td>1.11</td>
<td>1.03</td>
<td>0.62</td>
<td>0.69</td>
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<tr>
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<td>1.28</td>
<td>1.28</td>
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<tr>
<td>MF - High Rise - Common</td>
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### Savings Summary for Outdoor pipe insulation by System Type and Building Type (Δtherms per foot)

(continues for 3.5 pages)

#### Annual therm Savings per linear foot (therm /ft)

(2” pipe / 1” insulation for hot water, 2” insulation for steam)

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HP Steam

All buildings, Recirculation heating season only (Hours below 55F)

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HP Steam

All buildings, Recirculation year round (All hours)

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### Outdoor heating

Hot Water Space Heating with outdoor reset – non-recirculation

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<td>MF - High Rise - Residential</td>
<td></td>
<td>Grocery</td>
<td></td>
<td>13.51</td>
<td>13.46</td>
<td>11.80</td>
<td>7.36</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td></td>
<td>Healthcare Clinic</td>
<td></td>
<td>13.26</td>
<td>13.61</td>
<td>11.88</td>
<td>8.09</td>
</tr>
<tr>
<td>Movie Theater</td>
<td></td>
<td>High School</td>
<td></td>
<td>15.50</td>
<td>15.60</td>
<td>13.99</td>
<td>9.97</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td></td>
<td>Hospital - CAV no econ</td>
<td></td>
<td>14.82</td>
<td>15.27</td>
<td>13.01</td>
<td>11.19</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td></td>
<td>Hospital - CAV econ</td>
<td></td>
<td>15.02</td>
<td>15.57</td>
<td>13.27</td>
<td>11.50</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td></td>
<td>Hospital - VAV econ</td>
<td></td>
<td>6.14</td>
<td>5.84</td>
<td>4.39</td>
<td>2.64</td>
</tr>
<tr>
<td>Office - FCU</td>
<td></td>
<td>Hospital - FCU</td>
<td></td>
<td>11.13</td>
<td>12.71</td>
<td>10.35</td>
<td>12.16</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td></td>
<td>Hotel/Motel</td>
<td></td>
<td>14.80</td>
<td>14.38</td>
<td>12.97</td>
<td>8.87</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td></td>
<td>Hotel/Motel - Common</td>
<td></td>
<td>13.45</td>
<td>13.66</td>
<td>13.00</td>
<td>10.58</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td></td>
<td>Hotel/Motel - Guest</td>
<td></td>
<td>14.77</td>
<td>14.29</td>
<td>12.78</td>
<td>8.56</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td></td>
<td>Manufacturing Facility</td>
<td></td>
<td>8.80</td>
<td>8.51</td>
<td>7.89</td>
<td>4.77</td>
</tr>
<tr>
<td>Office - High Rise - Residential</td>
<td></td>
<td>MF - High Rise - Residential</td>
<td></td>
<td>15.43</td>
<td>15.31</td>
<td>13.92</td>
<td>12.05</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td></td>
<td>MF - Mid Rise</td>
<td></td>
<td>17.43</td>
<td>17.63</td>
<td>15.17</td>
<td>11.16</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td></td>
<td>Office - Low Rise</td>
<td></td>
<td>15.27</td>
<td>15.05</td>
<td>14.07</td>
<td>10.69</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td></td>
<td>Office - High Rise - CAV econ</td>
<td></td>
<td>16.97</td>
<td>17.22</td>
<td>15.70</td>
<td>10.51</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td></td>
<td>Office - Mid Rise</td>
<td></td>
<td>12.00</td>
<td>11.97</td>
<td>9.51</td>
<td>5.82</td>
</tr>
<tr>
<td>Office - High Rise - Low Rise</td>
<td></td>
<td>Restaurant</td>
<td></td>
<td>13.47</td>
<td>12.64</td>
<td>12.10</td>
<td>8.86</td>
</tr>
<tr>
<td>Office - High Rise - Residential</td>
<td></td>
<td>Retail - Department Store</td>
<td></td>
<td>11.34</td>
<td>11.38</td>
<td>10.21</td>
<td>7.73</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td></td>
<td>Retail - Strip Mall</td>
<td></td>
<td>11.69</td>
<td>10.74</td>
<td>10.08</td>
<td>6.56</td>
</tr>
</tbody>
</table>
For insulation covering elbows and tees that connect straight pipe, a calculated surface area will be assumed based on the dimensions for fittings given by ANSI/ASME B36.19. The surface area is then converted to an
equivalent length of pipe that must be added to the total length of straight pipe in order to calculate total savings. Equivalent pipe lengths are given in 1” increments in pipe diameter for simplicity. In the case of pipe diameters in between full inch diameters, the closest equivalent length should be used. The larger pipe sizes mostly apply to steam header piping, which has the most heat loss per foot.

### Calculated Surface Areas of Elbows and Tees

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter</th>
<th>Calculated Surface Area (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 Degree Elbow</td>
</tr>
<tr>
<td>1”</td>
<td>0.10</td>
</tr>
<tr>
<td>2”</td>
<td>0.41</td>
</tr>
<tr>
<td>3”</td>
<td>0.93</td>
</tr>
<tr>
<td>4”</td>
<td>1.64</td>
</tr>
<tr>
<td>5”</td>
<td>2.57</td>
</tr>
<tr>
<td>6”</td>
<td>3.70</td>
</tr>
<tr>
<td>8”</td>
<td>6.58</td>
</tr>
<tr>
<td>10”</td>
<td>10.28</td>
</tr>
<tr>
<td>12”</td>
<td>14.80</td>
</tr>
</tbody>
</table>

### Equivalent Length of Other Components – Elbows and Tees (L_{oc})

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter</th>
<th>Equivalent Length of Other Components (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 Degree Elbow</td>
</tr>
<tr>
<td>1”</td>
<td>0.30</td>
</tr>
<tr>
<td>2”</td>
<td>0.66</td>
</tr>
<tr>
<td>3”</td>
<td>1.01</td>
</tr>
<tr>
<td>4”</td>
<td>1.40</td>
</tr>
<tr>
<td>5”</td>
<td>1.76</td>
</tr>
<tr>
<td>6”</td>
<td>2.13</td>
</tr>
<tr>
<td>8”</td>
<td>2.91</td>
</tr>
<tr>
<td>10”</td>
<td>3.65</td>
</tr>
<tr>
<td>12”</td>
<td>4.44</td>
</tr>
</tbody>
</table>

For insulation around valves or flanges, a surface area from ASTM standard C1129-12 will be assumed for 2” pipes. For 1” pipes, which weren’t included in the standard, a linear-trended value will be used. The surface area is then converted to an equivalent length of either 1” or 2” straight pipe that must be added to the total length of straight pipe in order to calculate total savings.

### Calculated Surface Areas of Flanges and Valves

For insulation around valves or flanges, a surface area from ASTM standard C1129-12 will be assumed for 2” pipes. For 1” pipes, which weren’t included in the standard, a linear-trended value will be used. The surface area is then converted to an equivalent length of either 1” or 2” straight pipe that must be added to the total length of straight pipe in order to calculate total savings.

For insulation around valves or flanges, a surface area from ASTM standard C1129-12 will be assumed for 2” pipes. For 1” pipes, which weren’t included in the standard, a linear-trended value will be used. The surface area is then converted to an equivalent length of either 1” or 2” straight pipe that must be added to the total length of straight pipe in order to calculate total savings.

<table>
<thead>
<tr>
<th>Valves</th>
<th>Flanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class (psi)</td>
<td>150</td>
</tr>
<tr>
<td>NPS (in)</td>
<td>ft²</td>
</tr>
<tr>
<td>1</td>
<td>0.69</td>
</tr>
<tr>
<td>2</td>
<td>2.21</td>
</tr>
<tr>
<td>2.5</td>
<td>2.97</td>
</tr>
<tr>
<td>3</td>
<td>3.37</td>
</tr>
<tr>
<td>4</td>
<td>4.68</td>
</tr>
<tr>
<td>Class (psi)</td>
<td>150</td>
</tr>
<tr>
<td>NPS (in)</td>
<td>ft²</td>
</tr>
<tr>
<td>1</td>
<td>0.36</td>
</tr>
<tr>
<td>2</td>
<td>0.71</td>
</tr>
<tr>
<td>3</td>
<td>1.06</td>
</tr>
<tr>
<td>4</td>
<td>1.44</td>
</tr>
</tbody>
</table>

386 Based on the dimensions for diameter, long radius, and short radius given by ANSI/ASME 36.19

387 Based on the center to face and diameter dimensions given by ANSI/ASME B36.19
### Valves

<table>
<thead>
<tr>
<th>NPS (in)</th>
<th>150</th>
<th>300</th>
<th>600</th>
<th>900</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>7.03</td>
<td>9.71</td>
<td>13.03</td>
<td>15.8</td>
</tr>
<tr>
<td>8</td>
<td>10.3</td>
<td>13.5</td>
<td>18.4</td>
<td>23.8</td>
</tr>
<tr>
<td>10</td>
<td>13.8</td>
<td>18</td>
<td>26.5</td>
<td>32.1</td>
</tr>
<tr>
<td>12</td>
<td>16.1</td>
<td>24.1</td>
<td>31.9</td>
<td>41.9</td>
</tr>
</tbody>
</table>

### Flanges

<table>
<thead>
<tr>
<th>NPS (in)</th>
<th>150</th>
<th>300</th>
<th>600</th>
<th>900</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2.04</td>
<td>2.72</td>
<td>3.6</td>
<td>4.37</td>
</tr>
<tr>
<td>8</td>
<td>2.92</td>
<td>3.74</td>
<td>4.89</td>
<td>6.4</td>
</tr>
<tr>
<td>10</td>
<td>3.68</td>
<td>4.8</td>
<td>6.93</td>
<td>8.47</td>
</tr>
<tr>
<td>12</td>
<td>5.01</td>
<td>6.34</td>
<td>7.97</td>
<td>10.43</td>
</tr>
</tbody>
</table>

### Equivalent Length of Other Components - Flanges and Valves (L<sub>oc</sub>)

<table>
<thead>
<tr>
<th>ANSI Class (psi)</th>
<th>Equivalent Length of Other Components (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1&quot; Valve</td>
</tr>
<tr>
<td>150</td>
<td>3.56</td>
</tr>
<tr>
<td>300</td>
<td>4.73</td>
</tr>
<tr>
<td>600</td>
<td>4.73</td>
</tr>
<tr>
<td>900</td>
<td>8.37</td>
</tr>
</tbody>
</table>

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: CI-HVC-PINS-V04-160601

**Review Deadline: 1/1/2023**
4.4.15 Single-Package and Split System Unitary Air Conditioners

**DESCRIPTION**

This measure promotes the installation of high-efficiency unitary air-, water-, and evaporatively-cooled air conditioning equipment, both single-package and split systems. Air conditioning (AC) systems are a major consumer of electricity and systems that exceed baseline efficiency requirements can significantly reduce energy consumption. This measure could apply to the replacing of an existing unit at the end of its useful life or the installation of a new unit in a new or existing building.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is assumed to be a high-efficiency air-, water-, or evaporatively-cooled air conditioner that exceeds the energy efficiency requirements of the current International Energy Conservation Code (IECC).

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline equipment is assumed to be a standard-efficiency air-, water, or evaporatively-cooled air conditioner that meets the energy efficiency requirements of the IECC in effect on the date of the building permit (if date is unknown, assume current IECC code minimum).

For Early Replacement programs, use the actual efficiency of the existing unit or assume IECC code base in place at the original time of existing unit installation. To qualify under the early replacement characterization, baseline equipment must meet these additional qualifications:

- The existing unit is operational when replaced or the existing unit would be operational with minor repairs.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 years.

For early replacement, the remaining life of existing equipment is assumed to be 5 years.

**DEEMED MEASURE COST**

The incremental capital cost for this measure is based upon capacity and efficiency level (defined by CEE specifications), as outlined in the following table:

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Incremental cost ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to and including CEE Tier 1 units</td>
<td>CEE Tier 2 and above</td>
</tr>
<tr>
<td>&lt; 135,000 Btu/hr</td>
<td>$63</td>
</tr>
<tr>
<td>135,000 Btu/hr to &gt; 250,000 Btu/hr</td>
<td>$63</td>
</tr>
<tr>
<td>250,000 Btu/hr and greater</td>
<td>$19</td>
</tr>
</tbody>
</table>

---

388 Based on ComEd Small Business Trade Ally feedback. For units rated at less than 20 ton units, the cost of common repairs is under $2,000, significantly less than the cost of purchasing new equipment. Therefore, if the cost of repair is less than $2,000, it can be considered early replacement because customers would repair instead of replace a failed unit. Repair cost data was not available for units larger than 20 tons.


390 Assumed to be one third of effective useful life.

391 For specification details see: [https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0](https://library.cee1.org/content/cee-commercial-unitary-ac-and-hp-specification-0)

For early replacement the full cost of the installed unit should be used. If unknown use defaults below. The assumed deferred cost (after 5 years) of replacing existing equipment with a new baseline unit is also provided. This future cost should be discounted to present value using the real discount rate:

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Base Units</th>
<th>Up to and including CEE Tier 1 units</th>
<th>CEE Tier 2 and above</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 135,000 Btu/hr</td>
<td>$895</td>
<td>$958</td>
<td>$1,021</td>
</tr>
<tr>
<td>135,000 Btu/hr to &gt; 250,000 Btu/hr</td>
<td>$762</td>
<td>$825</td>
<td>$889</td>
</tr>
<tr>
<td>250,000 Btu/hr and greater</td>
<td>$673</td>
<td>$691</td>
<td>$710</td>
</tr>
</tbody>
</table>

LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market. Both values provided are based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren.

\[ \text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \]
\[ = 91.3\% \]  
\[ \text{CF}_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \]
\[ = 47.8\% \]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of Sale:

For units with cooling capacities less than 65 kBtu/hr:

\[ \Delta k\text{WH} = (\text{kBtu/hr}) \times \left( \frac{1}{\text{SEER}_{\text{base}}} - \frac{1}{\text{SEER}_{\text{ee}}} \right) \times \text{EFLH} \]

For units with cooling capacities equal to or greater than 65 kBtu/hr:

\[ \Delta k\text{WH} = (\text{kBtu/hr}) \times \left( \frac{1}{\text{IEER}_{\text{base}}} - \frac{1}{\text{IEER}_{\text{ee}}} \right) \times \text{EFLH} \]

Early replacement:

For units with cooling capacities less than 65 kBtu/hr:

393 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

394 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

395 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).
For remaining life of existing unit (1st 5 years):
\[ \Delta kWH = (kBtu/hr) \times [(1/SEERexist) - (1/SEERee)] \times EFLH \]

For remaining measure life (next 10 years):
\[ \Delta kWH = (kBtu/hr) \times [(1/SEERbase) - (1/SEERee)] \times EFLH \]

For units with cooling capacities equal to or greater than 65 kBtu/hr:
For remaining life of existing unit (1st 5 years):
\[ \Delta kWH = (kBtu/hr) \times [(1/IEERexist) - (1/IEERee)] \times EFLH \]

For remaining measure life (next 10 years):
\[ \Delta kWH = (kBtu/hr) \times [(1/IEERbase) - (1/IEERee)] \times EFLH \]

Where:
- \( kBtu/hr \) = capacity of the cooling equipment actually installed in kBtu per hour (1 ton of cooling capacity equals 12 kBtu/hr)
- \( SEERbase \) = Seasonal Energy Efficiency Ratio of the baseline equipment
  - SEER values from tables below, based on applicable IECC on date of building permit (if unknown assume IECC 2015).
- \( SEERee \) = Seasonal Energy Efficiency Ratio of the energy efficient equipment (actually installed)
- \( SEERexist \) = Seasonal Energy Efficiency Ratio of the existing equipment
  - Actual, or assume IECC code base in place at the original time of existing unit installation
- \( IEERbase \) = Integrated Energy Efficiency Ratio of the baseline equipment. See table below based on applicable IECC on date of building permit (if unknown assume IECC 2015).
- \( IEERee \) = Integrated Energy Efficiency Ratio of the energy efficient equipment (actually installed)
- \( IEERexist \) = Integrated Energy Efficiency Ratio of the existing equipment
  - Actual, or assume IECC code base in place at the original time of existing unit installation
- \( EFLH \) = Equivalent Full Load Hours for cooling are provided in section 4.4 HVAC End Use

The rating conditions for the baseline and efficient equipment efficiencies must be equivalent.
### 2012 IECC Minimum Efficiency Requirements

#### TABLE C403.2.3(1)

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>HEATING SECTION TYPE</th>
<th>SUBCATEGORY OR RATING CONDITION</th>
<th>MINIMUM EFFICIENCY Before 6/1/2011</th>
<th>MINIMUM EFFICIENCY As of 6/1/2011</th>
<th>TEST PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioners, air cooled</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>13.0 SEER</td>
<td>13.0 SEER</td>
<td>AHR 210/240</td>
</tr>
<tr>
<td></td>
<td>≤ 30,000 Btu/h</td>
<td>All</td>
<td>Single Package</td>
<td>13.0 SEER</td>
<td>13.0 SEER</td>
<td></td>
</tr>
<tr>
<td>Through-the-wall (air cooled)</td>
<td>≤ 55,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>12.0 SEER</td>
<td>12.0 SEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≤ 30,000 Btu/h</td>
<td>All</td>
<td>Single Package</td>
<td>12.0 SEER</td>
<td>12.0 SEER</td>
<td></td>
</tr>
<tr>
<td>Small-duct high-velocity (air cooled)</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>10.0 SEER</td>
<td>10.0 SEER</td>
<td>AHR 210/240</td>
</tr>
<tr>
<td></td>
<td>≥ 65,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.2 EER</td>
<td>11.2 EER</td>
<td>AHR 340/360</td>
</tr>
<tr>
<td></td>
<td>&lt; 135,000 Btu/h</td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.2 EER</td>
<td>11.2 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.0 EER</td>
<td>11.0 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 240,000 Btu/h</td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.0 EER</td>
<td>11.0 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td>10.8 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 760,000 Btu/h</td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td>10.8 EER</td>
<td></td>
</tr>
<tr>
<td>Air conditioners, water cooled</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System</td>
<td>12.1 EER</td>
<td>12.1 EER</td>
<td>AHR 210/240</td>
</tr>
<tr>
<td></td>
<td>≥ 65,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.5 EER</td>
<td>11.5 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 135,000 Btu/h</td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.3 EER</td>
<td>11.3 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.0 EER</td>
<td>11.0 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 240,000 Btu/h</td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td>10.8 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td>10.8 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 760,000 Btu/h</td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td>10.8 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 760,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td>10.8 EER</td>
<td></td>
</tr>
</tbody>
</table>
## TABLE C403.2.3(c)—continued

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>HEATING SECTION TYPE</th>
<th>SUB-CATEGORY OR RATING CONDITION</th>
<th>MINIMUM EFFICIENCY</th>
<th>TEST PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioners, evaporatively cooled</td>
<td>&lt; 65,000 Btu/h</td>
<td>All</td>
<td>Split System and Single Package</td>
<td>12.1 EER 12.3 IEEER</td>
<td>AHRI 210/240</td>
</tr>
<tr>
<td></td>
<td>≥ 65,000 Btu/h and &lt; 135,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.5 EER 12.1 IEEER</td>
<td>AHRI 340/360</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.3 EER 12.1 IEEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Btu/h and &lt; 240,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.0 EER 12.0 IEEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>10.8 EER 11.0 IEEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Btu/h and &lt; 760,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.0 EER 12.1 IEEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>10.8 EER 10.9 IEEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 760,000 Btu/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>10.0 EER 11.1 IEEER</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>10.8 EER 10.9 IEEER</td>
<td></td>
</tr>
<tr>
<td>Condensing units, air cooled</td>
<td>≥ 135,000 Btu/h</td>
<td>All</td>
<td></td>
<td>10.1 EER 11.4 IEEER</td>
<td>AHRI 365</td>
</tr>
<tr>
<td>Condensing units, water cooled</td>
<td>≥ 135,000 Btu/h</td>
<td>All</td>
<td></td>
<td>13.1 EER 13.6 IEEER</td>
<td></td>
</tr>
<tr>
<td>Condensing units, evaporatively cooled</td>
<td>≥ 135,000 Btu/h</td>
<td>All</td>
<td></td>
<td>13.1 EER 13.6 IEEER</td>
<td></td>
</tr>
</tbody>
</table>

For SI: 1 British thermal unit per hour = 0.2931 W.
a. Chapter 6 of the referenced standard contains a complete specification of the referenced test procedure, including the reference year version of the test procedure.
b. Single-phase, air-cooled air conditioners less than 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.
### 2015 IECC Minimum Efficiency Requirements

**TABLE C403.2.3(1)**

**MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS**

<table>
<thead>
<tr>
<th>EQUIPMENT TYPE</th>
<th>SIZE CATEGORY</th>
<th>HEATING SECTION TYPE</th>
<th>SUBCATEGORY OR RATING CONDITION</th>
<th>MINIMUM EFFICIENCY</th>
<th>TEST PROCEDURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air conditioners, air cooled</td>
<td>&lt; 65,000 Brt/h</td>
<td>All</td>
<td>Split System</td>
<td>13.0 SEER</td>
<td>AHRI 210/240</td>
</tr>
<tr>
<td>Through-the-wall (air cooled)</td>
<td>≤ 30,000 Brt/h</td>
<td>All</td>
<td>Split system</td>
<td>12.0 SEER</td>
<td></td>
</tr>
<tr>
<td>Small-duct high-velocity (air cooled)</td>
<td>&lt; 65,000 Brt/h</td>
<td>All</td>
<td>Single Package</td>
<td>12.0 SEER</td>
<td>AHRI 210/240</td>
</tr>
<tr>
<td>Air conditioners, air cooled</td>
<td>≥ 65,000 Brt/h and &lt; 135,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.2 EER</td>
<td>AHRI 340/360</td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.6 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Brt/h and &lt; 240,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>11.0 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.2 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Brt/h and &lt; 760,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>10.8 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>11.0 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 760,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>9.5 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>9.6 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air conditioners, water cooled</td>
<td>&lt; 65,000 Brt/h</td>
<td>All</td>
<td>Split System and Single Package</td>
<td>12.1 EER</td>
<td>AHRI 210/240</td>
</tr>
<tr>
<td></td>
<td>≥ 65,000 Brt/h and &lt; 135,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>12.1 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>12.3 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 135,000 Brt/h and &lt; 240,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>12.5 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>12.7 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 240,000 Brt/h and &lt; 760,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>12.4 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>12.6 EER</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 760,000 Brt/h</td>
<td>Electric Resistance (or None)</td>
<td>Split System and Single Package</td>
<td>12.2 EER</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All other</td>
<td>Split System and Single Package</td>
<td>12.4 EER</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continued)
\[ \Delta k\text{WH} = (60) \times [(1/13) - (1/15)] \times 950 \]
\[ = 585 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of Sale:
\[ \Delta kW = (k\text{Btu/hr \times } (1/\text{EERbase} - 1/\text{EERee})) \times CF \]

Early Replacement:
For remaining life of existing unit (1st 5 years):
\[ \Delta kW = (k\text{Btu/hr} \times [(1/\text{EERexist}) - (1/\text{EERee})]) \times CF \]

For remaining measure life (next 10 years):
\[ \Delta kWh = (k\text{Btu/hr} \times [(1/\text{EERbase}) - (1/\text{EERee})]) \times CF \]

Where:
- \( \text{EERbase} \) = Energy Efficiency Ratio of the baseline equipment
- = EER values from tables below, based on applicable IECC on date of the building permit (if unknown assume IECC 2015). (For air-cooled units < 65 kBTU/hr, assume the following
conversion from SEER to EER for calculation of peak savings: \[ EER = (-0.02 \times SEER^2) + (1.12 \times SEER) \]

EERee = Energy Efficiency Ratio of the energy efficient equipment. If the actual EERee is unknown, assume the conversion from SEER to EER for calculation of peak savings as above.

EEExist = Energy Efficiency Ratio of the existing equipment

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \]
\[ = 91.3\% \]

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \]
\[ = 47.8\% \]

For example, a 5 ton air cooled split system with a SEER of 15 in Rockford would save:

\[ \Delta k\text{W}_{SSP} = (60) \times [(1/13) - (1/15)] \times 0.913 \]
\[ = 0.562 \text{ kW} \]

**Natural Gas Energy Savings**

N/A

**Water Impact Descriptions and Calculation**

N/A

**Measure Code:** CI-HVC-SPUA-V05-180101

**Review Deadline:** 1/1/2019

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397 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

398 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
4.4.16 Steam Trap Replacement or Repair

DESCRIPTION

The measure is for the repair or replacement of faulty steam traps that are allowing excess steam to escape and thereby increasing steam generation. The measure is applicable to commercial applications, commercial HVAC (low pressure steam) including multifamily buildings, low pressure industrial applications, medium pressure industrial applications, applications and high pressure industrial applications.

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

DEFINITION OF EFFICIENT EQUIPMENT

Customers must have leaking traps to qualify for rebates. However, if a commercial customer opts to replace all traps without inspection, rebates and the savings are discounted to take into consideration the fact that some traps are being replaced that have not yet failed.

DEFINITION OF BASELINE EQUIPMENT

The baseline criterion is a faulty steam trap in need of replacing. No minimum leak rate is required. Any leaking or blow through trap can be repaired or replaced. If a commercial customer chooses to repair or replace all the steam traps at the facility without verification, the savings are adjusted. Savings for commercial full replacement projects are reduced by the percentage of traps found to be leaking on average from the studies listed. If an audit is performed on a commercial site, then the leaking and blowdown can be adjusted.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The life of this measure is 6 years\(^ {399}\)

DEEMED MEASURE COST

<table>
<thead>
<tr>
<th>Steam System</th>
<th>Cost per trap(^ {400}) ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Dry Cleaners</td>
<td>77</td>
</tr>
<tr>
<td>Commercial Heating (including Multifamily), low pressure steam</td>
<td>77</td>
</tr>
<tr>
<td>Industrial Medium Pressure $&gt;15$ psig $&lt;30$ psig</td>
<td>180</td>
</tr>
<tr>
<td>Steam Trap, Industrial Medium Pressure $\geq30$ $&lt;75$ psig</td>
<td>223</td>
</tr>
<tr>
<td>Steam Trap, Industrial High Pressure $\geq75$ $&lt;125$ psig</td>
<td>276</td>
</tr>
<tr>
<td>Steam Trap, Industrial High Pressure $\geq125$ $&lt;175$ psig</td>
<td>322</td>
</tr>
<tr>
<td>Steam Trap, Industrial High Pressure $\geq175$ $&lt;250$ psig</td>
<td>370</td>
</tr>
<tr>
<td>Steam Trap, Industrial High Pressure $\geq250$ psig</td>
<td>418</td>
</tr>
</tbody>
</table>

LOADSHAPE

N/A

\(^{399}\)Source paper is the CLEAResult "Steam Traps Revision #1" dated August 2011. Primary studies used to prepare the source paper include Enbridge Steam Trap Survey, KW Engineering Steam Trap Survey, Enbridge Steam Saver Program 2005, Armstrong Steam Trap Survey, DOE Federal Energy Management Program Steam Trap Performance Assessment, Oak Ridge National Laboratory Steam System Survey Guide, KEMA Evaluation of PG&E's Steam Trap Program, Sept. 2007. Communication with vendors suggested an inverted bucket steam trap life typically in the range of 5 - 7 years, float and thermostatic traps 4-6 years, float and thermodynamic disc traps of 1-3 years. Cost does not include installation.

\(^{400}\)Ibid.
COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF SAVINGS

ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS SAVINGS

\[ \Delta \text{Therm} = \text{Sa} \times (Hv/B) \times \text{Hours} \times \frac{L}{100,000} \]

Where:
\[ \text{Sa} = \text{Average actual steam loss per leaking trap} \]
\[ = 24.24 \times \text{Pia} \times D^2 \times A \times \text{FF} \]

Where:
\[ 24.24 = \text{Constant lb/(hr-psia-in}^2) \]
\[ \text{Pia} = \text{Pig} + \text{Patm} \]
\[ = \text{Average steam trap inlet pressure, absolute, psia} \]
\[ \text{Pig} = \text{Average steam trap inlet pressure, gauge, psig} \]
\[ \text{Patm} = \text{Atmospheric pressure, 14.7 psia} \]
\[ D = \text{Diameter of Orifice, in.} \]
\[ A = \text{Adjustment factor} \]
\[ = 50\%,^{401} \text{ all steam systems. This factor is to account for reducing the maximum theoretical steam flow to the average steam flow (the Enbridge factor).} \]
\[ \text{FF} = \text{Flow Factor. In addition to the Adjustment factor (A), an additional 50 percent flow factor adjustment is recommended for medium and high pressure steam systems to address industrial float and thermostatic style traps where additional blockage is possible.} \]

^{401} \text{Enbridge adjustment factor used as referenced in CLEAResult “Work Paper Steam Traps Revision #2” Revision 3 dated March 2, 2012 and DOE Federal Energy Management Program Steam Trap Performance Assessment.}
### Steam Trap Replacement or Repair

#### Steam System

<table>
<thead>
<tr>
<th>Steam System</th>
<th>Average Steam Trap Inlet Pressure psig</th>
<th>Diameter of Orifice in</th>
<th>Adjustment Factor</th>
<th>Flow Factor</th>
<th>Average Actual Steam Loss per Leaking Trap (lb/hr/trap)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Dry Cleaners</td>
<td>-</td>
<td>-</td>
<td>50%</td>
<td>100%</td>
<td>19.1</td>
</tr>
<tr>
<td>Commercial Heating (including Multifamily) LPS</td>
<td>-</td>
<td>-</td>
<td>50%</td>
<td>100%</td>
<td>6.9</td>
</tr>
<tr>
<td>Industrial or Process Low Pressure, &lt;15 psig</td>
<td>-</td>
<td>-</td>
<td>50%</td>
<td>100%</td>
<td>6.9</td>
</tr>
<tr>
<td>Medium Pressure &gt;15 psig &lt; 30 psig</td>
<td>16</td>
<td>0.1875</td>
<td>50%</td>
<td>50%</td>
<td>6.5</td>
</tr>
<tr>
<td>Medium Pressure ≥30 &lt;75 psig</td>
<td>47</td>
<td>0.2500</td>
<td>50%</td>
<td>50%</td>
<td>23.4</td>
</tr>
<tr>
<td>High Pressure ≥75 &lt;125 psig</td>
<td>101</td>
<td>0.2500</td>
<td>50%</td>
<td>50%</td>
<td>43.8</td>
</tr>
<tr>
<td>High Pressure ≥125 &lt;175 psig</td>
<td>146</td>
<td>0.2500</td>
<td>50%</td>
<td>50%</td>
<td>60.9</td>
</tr>
<tr>
<td>High Pressure ≥175 &lt;250 psig</td>
<td>202</td>
<td>0.2500</td>
<td>50%</td>
<td>50%</td>
<td>82.1</td>
</tr>
<tr>
<td>High Pressure ≥250 ≤300 psig</td>
<td>263</td>
<td>0.2500</td>
<td>50%</td>
<td>50%</td>
<td>105.2</td>
</tr>
<tr>
<td>High Pressure &gt; 300 psig</td>
<td>Custom</td>
<td>Custom</td>
<td>50%</td>
<td>50%</td>
<td>Calculated</td>
</tr>
</tbody>
</table>

#### Hv = Heat of vaporization of steam

<table>
<thead>
<tr>
<th>Steam System</th>
<th>Average Inlet Pressure psig</th>
<th>Heat of Vaporization (Btu/lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Dry Cleaners</td>
<td>--</td>
<td>890</td>
</tr>
<tr>
<td>Commercial Heating (including Multifamily) LPS</td>
<td>--</td>
<td>951</td>
</tr>
<tr>
<td>Industrial and Process Low Pressure ≤15 psig</td>
<td>--</td>
<td>951</td>
</tr>
<tr>
<td>Medium Pressure &gt;15 psig &lt; 30 psig</td>
<td>16</td>
<td>944</td>
</tr>
<tr>
<td>Medium Pressure ≥30 &lt;75 psig</td>
<td>47</td>
<td>915</td>
</tr>
<tr>
<td>High Pressure ≥75 &lt;125 psig</td>
<td>101</td>
<td>880</td>
</tr>
<tr>
<td>High Pressure ≥125 &lt;175 psig</td>
<td>146</td>
<td>859</td>
</tr>
<tr>
<td>High Pressure ≥175 &lt;250 psig</td>
<td>202</td>
<td>837</td>
</tr>
<tr>
<td>High Pressure ≥250 ≤300 psig</td>
<td>263</td>
<td>816</td>
</tr>
<tr>
<td>High Pressure &gt; 300 psig</td>
<td>--</td>
<td>Custom</td>
</tr>
</tbody>
</table>

#### B = Boiler efficiency

- custom, if unknown:
  - 80.7% for steam boilers, except multifamily low-pressure 404
  - 64.8% for multifamily low-pressure steam boilers 405

#### Hours = Annual operating hours of steam plant

---

402 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.

403 Heat of vaporization of steam at the inlet pressure to the steam trap. Implicit assumption that the average boiler nominal pressure where the vaporization occurs, is essentially that same pressure. Referenced in CLEAResult “Work Paper Steam Traps Revision #2” Revision 3 dated March 2, 2012.

404 Ibid.

= custom, if unknown:

<table>
<thead>
<tr>
<th>Steam System</th>
<th>Zone (where applicable)</th>
<th>Hours/Yr 406</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Dry Cleaners</td>
<td>All Climate Zones</td>
<td>2,425</td>
</tr>
<tr>
<td>Industrial and Process Low Pressure ≤15 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>Medium Pressure &gt;15 psig &lt; 30 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>Medium Pressure ≥30 &lt;75 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>High Pressure ≥75 &lt;125 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>High Pressure ≥125 &lt;175 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>High Pressure ≥175 &lt;250 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>High Pressure ≥250 psig</td>
<td></td>
<td>8,282</td>
</tr>
<tr>
<td>Commercial Heating (including Multifamily)LPS 407</td>
<td>1 (Rockford)</td>
<td>4,272</td>
</tr>
<tr>
<td></td>
<td>2 (Chicago O’Hare)</td>
<td>4,029</td>
</tr>
<tr>
<td></td>
<td>3 (Springfield)</td>
<td>3,406</td>
</tr>
<tr>
<td></td>
<td>4 (Belleville)</td>
<td>2,515</td>
</tr>
<tr>
<td></td>
<td>5 (Marion)</td>
<td>2,546</td>
</tr>
</tbody>
</table>

L = Leaking & blow-thru

L is 1.0 when applied to the replacement of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, the leaking and blow-thru is applied to reflect the assumed percentage of steam traps that were actually leaking and need to be replaced. A custom value can be utilized if supported by an evaluation.

<table>
<thead>
<tr>
<th>Steam System</th>
<th>L (%) 408</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custom</td>
<td>Custom</td>
</tr>
<tr>
<td>Commercial Dry Cleaners</td>
<td>27%</td>
</tr>
<tr>
<td>Commercial Heating (including Multifamily) LPS</td>
<td>27%</td>
</tr>
<tr>
<td>Industrial and Process Low Pressure ≤15 psig</td>
<td>16%</td>
</tr>
<tr>
<td>Medium Pressure &gt;15 psig &lt; 30 psig</td>
<td>16%</td>
</tr>
<tr>
<td>Medium Pressure ≥30 &lt;75 psig</td>
<td>16%</td>
</tr>
<tr>
<td>High Pressure ≥75 &lt;125 psig</td>
<td>16%</td>
</tr>
<tr>
<td>High Pressure ≥125 &lt;175 psig</td>
<td>16%</td>
</tr>
<tr>
<td>High Pressure ≥175 &lt;250 psig</td>
<td>16%</td>
</tr>
<tr>
<td>High Pressure &gt; 300 psig</td>
<td>16%</td>
</tr>
</tbody>
</table>

406 Medium and high pressure steam trap annual operating hours 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.

407 Since commercial LPS reflect heating systems, Hours/yr are equivalent to HDD55 zone table.

408 Dry cleaners survey data as referenced in CLEAResult “Work Paper Steam Traps Revision #2” Revision 3 dated March 2, 2012.
EXAMPLE
For example, a commercial dry cleaning facility with the default hours of operation and boiler efficiency;
\[ \Delta \text{Therms} = S_a \times (H_v/B) \times \text{Hours} \times L \]
\[ = 19.1 \text{ lbs/hr/trap} \times (890 \text{ Btu/lb / 80%})/100,000 \times 2,425 \times 27\% \]
\[ = 138.8 \text{ therms per trap} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-STRE-V05-180101

REVIEW DEADLINE: 1/1/2020
4.4.17 Variable Speed Drives for HVAC Pumps and Cooling Tower Fans

DESCRIPTION

This measure is applied to variable speed drives (VSD) which are installed on the following HVAC system applications: chilled water pump, hot water pumps and cooling tower fans. There is a separate measure for HVAC supply and return fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

This measure is not applicable for:

- Cooling towers, chilled or hot water pumps with any process load.
- VSD installation in existing cooling towers with 2-speed motors. (IECC 2007 requires 2-speed motors for cooling towers with motors greater than 7.5 HP)
- VSD installation in new cooling towers with motors greater than 7.5 HP

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

DEFINITION OF EFFICIENT EQUIPMENT

The VSD is applied to a motor which does not have a VSD. This measure is not applicable for replacing failed VSDs. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

DEFINITION OF BASELINE EQUIPMENT

The time of sale baseline is a new motor installed without a VSD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for HVAC application is 15 years; measure life for process is 10 years.

DEEMED MEASURE COST

Customer provided costs will be used when available. Default measure costs are noted below for up to 20 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

<table>
<thead>
<tr>
<th>HP</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5 HP</td>
<td>$1,330</td>
</tr>
<tr>
<td>7.5 HP</td>
<td>$1,622</td>
</tr>
<tr>
<td>10 HP</td>
<td>$1,898</td>
</tr>
<tr>
<td>15 HP</td>
<td>$2,518</td>
</tr>
<tr>
<td>20 HP</td>
<td>$3,059</td>
</tr>
</tbody>
</table>

---

409 Efficiency Vermont TRM 10/26/11 for HVAC VSD motors
410 DEER 2008
LOADSHAPE

Loadshape C42 - VFD - Boiler feedwater pumps <10 HP
Loadshape C43 - VFD - Chilled water pumps <10 HP
Loadshape C44 - VFD Boiler circulation pumps <10 HP
Loadshape C48 - VFD Boiler draft fans <10 HP
Loadshape C49 - VFD Cooling Tower Fans <10 HP

COINCIDENCE FACTOR

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \frac{\text{BHP}}{\text{EFFi}} \times \text{Hours} \times \text{ESF} \]

Where:

- **BHP**: System Brake Horsepower
  (Nominal motor HP * Motor load factor)
  Motors are assumed to have a load factor of 65% for calculating kW if actual values cannot be determined. Custom load factor may be applied if known.

- **EFFi**: Motor efficiency, installed. Actual motor efficiency shall be used to calculate kW. If not known a default value of 93% shall be used.

- **Hours**: Default hours are provided for HVAC applications which vary by HVAC application and building type. When available, actual hours should be used.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Heating Run Hours</th>
<th>Cooling Run Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>4888</td>
<td>2150</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>4711</td>
<td>4373</td>
</tr>
<tr>
<td>College</td>
<td>3990</td>
<td>1605</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>4136</td>
<td>2084</td>
</tr>
<tr>
<td>Elementary School</td>
<td>5105</td>
<td>3276</td>
</tr>
<tr>
<td>Garage</td>
<td>4849</td>
<td>2102</td>
</tr>
<tr>
<td>Grocery</td>
<td>4200</td>
<td>2096</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>5481</td>
<td>1987</td>
</tr>
<tr>
<td>High School</td>
<td>5480</td>
<td>3141</td>
</tr>
</tbody>
</table>


414 Hours per year are estimated using the eQuest models as the total number of hours the heating or cooling system is operating for each building type. “Heating and Cooling Run Hours” are estimated as the total number of hours fans are operating for heating, cooling and ventilation for each building type. This may overclaim certain applications (e.g. pumps) and so where possible actual hours should be used for these applications.
<table>
<thead>
<tr>
<th>Building Type</th>
<th>Heating Run Hours</th>
<th>Cooling Run Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital - VAV econ</td>
<td>3718</td>
<td>2788</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>7170</td>
<td>2881</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>7139</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>5844</td>
<td>8729</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>3821</td>
<td>2805</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>4522</td>
<td>4237</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>5749</td>
<td>2899</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>4480</td>
<td>4479</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>3292</td>
<td>8712</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>5063</td>
<td>2120</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>4094</td>
<td>2038</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td>5361</td>
<td>4849</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td>5331</td>
<td>5682</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td>3758</td>
<td>3069</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>3834</td>
<td>2481</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>3977</td>
<td>1881</td>
</tr>
<tr>
<td>Religious Building</td>
<td>5199</td>
<td>2830</td>
</tr>
<tr>
<td>Restaurant</td>
<td>4579</td>
<td>3350</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>4249</td>
<td>2528</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>4475</td>
<td>2266</td>
</tr>
<tr>
<td>Warehouse</td>
<td>4606</td>
<td>770</td>
</tr>
<tr>
<td>Unknown</td>
<td>4649</td>
<td>2718</td>
</tr>
</tbody>
</table>

The type of hours to apply depends on the VFD application, according to the table below.

<table>
<thead>
<tr>
<th>Application</th>
<th>Hours Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Pump</td>
<td>Heating</td>
</tr>
<tr>
<td>Chilled Water Pump</td>
<td>Cooling</td>
</tr>
<tr>
<td>Cooling Tower Fan</td>
<td>Cooling</td>
</tr>
</tbody>
</table>

ESF = Energy savings factor varies by VFD application. Units are kW/HP.

<table>
<thead>
<tr>
<th>Application</th>
<th>ESF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Pump</td>
<td>0.424416</td>
</tr>
<tr>
<td>Chilled Water Pump</td>
<td>0.411416</td>
</tr>
<tr>
<td>Cooling Tower Fan</td>
<td>0.126417</td>
</tr>
</tbody>
</table>

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$\Delta kW = \text{BHP/EFFi} \times \text{DSF}$$

Where:

DSF = Demand Savings Factor varies by VFD application. Units are kW/HP. Values listed below are based on typical peak load for the listed application.

415 Based on the methodology described in the Connecticut TRM, 8th Edition (2013); derived using a temperature BIN analysis of typical heating, cooling and fan load profiles.

416 Ibid

417 Based on eQuest model for VSD v one-speed fan, see “CT Savings Factors.xlsx”.

418 DSF assumptions are based upon the same source as the ESFs.
### Fossil Fuel Impact Descriptions and Calculation

There are no expected fossil fuel impacts for this measure.

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

**Measure Code:** CI-HVC-VSDHP-V04-180101

**Review Deadline:** 1/1/2021
4.4.18 Small Commercial Programmable Thermostats

DESCRIPTION

This measure characterizes the energy savings from the installation of a new Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. This measure is limited to small businesses, as they have smaller HVAC systems that are similar to residential HVAC systems and may be controlled by a simple manual adjustment thermostat. Mid to large sized businesses will typically have a building automation system or some other form of automated HVAC controls. Therefore, it is limited to select building types, including small office, retail – strip mall, restaurants (characterized as 1, 2 or 3 meal), small manufacturing, religious facilities, and convenience stores. This measure is only appropriate for single zone heating systems. Custom calculations are required for savings for programmable thermostats installed in multi-zone systems.

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention.

DEFINITION OF BASELINE EQUIPMENT

For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life of a programmable thermostat is assumed to be 8 years\textsuperscript{419} based upon equipment life only\textsuperscript{420}. For the purposes of claiming savings for a new programmable thermostat, this is reduced by a 50% persistence factor to give a final measure life of 4 years.

DEEMED MEASURE COST

Actual material and labor costs should be used if the implementation method allows. If unknown the capital and labor cost for this measure is assumed to be $181 per thermostat\textsuperscript{421}. For the purposes of screening and planning it should be assumed that one thermostat will serve 5 tons of Cooling Capacity at a cost of $36.20 / ton or 115kBtuh of Heating Capacity at a cost of $1.57 / kBtu.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

\textsuperscript{419} Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

\textsuperscript{420} Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer term impacts should be assessed.

\textsuperscript{421} Nicor Rider 30 Business EER Program Database, Paid Rebates with Programmable Thermostat Installation Costs, Program to Date as of January 11, 2013.
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta k\text{W} = [\text{Baseline Energy Use (kWh/Ton)} - \text{Proposed Energy Use (kWh/Ton)}] * \text{Cooling Capacity (Tons)}
\]

The following equations are used to calculate baseline and proposed electric energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>(CZ + Fu^* (0.83<em>Tc + 0.83</em>Th + 1.67<em>Ws - 293.018) - 0.0922</em>Tc + 1.291*Ws)</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + Fu^* (1.911 - 0.12<em>Tc) + Tc^</em> (0.00311<em>Ws - 0.229) + 0.11</em>Ws)</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>(CZ + Fu^* (-28.629<em>Tc - 11.69</em>Th + 19.118<em>Ws - 2935.12) + 0.909</em>Ws)</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + Tc^* (0.0863<em>Ws - 12.688) + Th^</em> (0.043<em>Ws - 6.38) + 1.669</em>Ws)</td>
</tr>
<tr>
<td>Office – Low Rise</td>
<td>Continuous</td>
<td>(CZ + Fu^* (7.082<em>Tc - 41.199</em>Th + 18.734<em>Ws - 3288.55) + Tc^</em> (0.205*Ws - 34.929))</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + Tc^* (0.0864<em>Ws - 8.984) + Th^</em> (0.0864<em>Ws - 9.558) + 1.178</em>Ws)</td>
</tr>
<tr>
<td>Religious</td>
<td>Continuous</td>
<td>(CZ + Fu^* (-1.579<em>Tc - 18.14</em>Th + 15.01<em>Ws - 2417.74) + Tc^</em> (0.177*Ws - 26.412))</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + Fu^* (0.266<em>Tc - 2.067) + Tc^</em> (0.0295<em>Ws - 4.502) + Th^</em> (0.0517<em>Ws - 8.251) + 0.735</em>Ws)</td>
</tr>
<tr>
<td>Restaurant – Fast Food</td>
<td>Continuous</td>
<td>(CZ + Fu^* (0.678<em>Tc + 0.257</em>Th + 2.88<em>Ws - 494.006) + Tc^</em> (0.0231<em>Ws - 4.074) + Th^</em> (0.00936<em>Ws - 1.655) + 0.918</em>Ws)</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + Fu^* (0.377<em>Tc + 0.124</em>Th + 0.13<em>Ws - 24.893) + Tc^</em> (-0.0143<em>Th + 0.0166</em>Ws - 2.691) + 0.898*Ws)</td>
</tr>
<tr>
<td>Restaurant – Full Service</td>
<td>Continuous</td>
<td>(CZ + Fu^* (-8.41<em>Th + 11.766</em>Ws - 1910.81) + Tc^* (0.282*Ws - 43.851))</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + 0.123<em>Fu^+ Tc^+ Tc^</em> (0.0561<em>Ws - 8.237) + Th^</em> (0.0219<em>Ws - 3.284) + 1.038</em>Ws)</td>
</tr>
<tr>
<td>Retail – Department Store</td>
<td>Continuous</td>
<td>(CZ + Fu^* (-1.475<em>Th + 0.755</em>Ws - 114.373) + Tc^* (0.151<em>Ws - 24.016) + 1.612</em>Ws)</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + Tc^* (0.0173<em>Ws - 1.912) + Th^</em> (0.0249<em>Ws - 3.29) + 0.511</em>Ws)</td>
</tr>
<tr>
<td>Retail – Strip Mall</td>
<td>Continuous</td>
<td>(CZ + Fu^* (1.077<em>Tc - 10.697</em>Th + 6.91<em>Ws - 1117.18) + Tc^</em> (0.0583<em>Ws - 7.54) + 1.231</em>Ws)</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(CZ + 0.0894<em>Fu^+ Tc^+ Th^</em> (-0.0142<em>Th + 0.04</em>Ws - 5.278) + 0.884*Ws)</td>
</tr>
</tbody>
</table>

Where:

- \(CZ\) = Climate Zone Coefficient
  
  Depends on Building Type and Fan Mode During Occupied Period (see table below)

- \(Tc\) = Degrees of Cooling Setback \(^\circ\)F
  
  Must be between 0-15\(^\circ\)F

- \(Th\) = Degrees of Heating Setback \(^\circ\)F
  
  Must be between 0-15\(^\circ\)F

Fo = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)
= Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)
= Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Fu = Fan Mode During Unoccupied Period
= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)
= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Ws = Weekly Hours thermostat is in Occupied mode
= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)
(e.g.: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59)

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Climate Zone Coefficient (CZ)423</th>
<th>Minimum Ws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>911.366 928.924 1152.83 1208.999 1210.173</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>735.752 762.831 966.562 998.927 1028.906</td>
<td>108</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>4817.094 4832.784 5139.133 5182.161 5208.608</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>1478.133 1514.568 1784.384 1843.463 1930.47</td>
<td>133</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>Continuous</td>
<td>5047.662 5039.592 5187.924 5217.672 5177.449</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>825.072 808.965 946.571 979.421 945.418</td>
<td>117</td>
</tr>
<tr>
<td>Religious Facility</td>
<td>Continuous</td>
<td>4197.117 4172.858 4380.025 4370.008 4356.054</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>632.404 603.395 678.294 664.717 616.853</td>
<td>93</td>
</tr>
<tr>
<td>Restaurant – Fast Food</td>
<td>Continuous</td>
<td>1342.988 1378.661 1664.018 1714.201 1727.841</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>993.764 1039.643 1307.8 1340.544 1389.791</td>
<td>117</td>
</tr>
<tr>
<td>Restaurant – Full Service</td>
<td>Continuous</td>
<td>4070.35 4094.742 4428.966 4501.829 4522.522</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>1472.014 1516.05 1856.108 1938.441 2056.45</td>
<td>93</td>
</tr>
<tr>
<td>Retail – Department Store</td>
<td>Continuous</td>
<td>1510.201 1496.47 1706.105 1716.128 1688.464</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>701.27 702.129 847.735 875.12 881.677</td>
<td>93</td>
</tr>
<tr>
<td>Retail – Strip Mall</td>
<td>Continuous</td>
<td>1926.294 1930.137 2156.856 2174.435 2169.03</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>656.479 673.257 835.906 850.322 869.921</td>
<td>93</td>
</tr>
</tbody>
</table>

423 Climate Zones Reference in Section 3.7, Table 3.6
EXAMPLE

A low rise office in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and has a 10 ton DX RTU controlled by a manual thermostat. The fan runs continuously during the occupied hours and building staff do not manually change the fan mode, cooling or heating setpoints during unoccupied periods.

A programmable thermostat is installed by a contractor who sets the occupied schedule to Mon-Fri 7AM-6PM with a 10°F cooling and heating unoccupied temperature setback. The contractor also programs the fan to operate continuously during the occupied periods and to intermittent “auto” during the unoccupied periods.

\[ \Delta \text{kWh} = [\text{Baseline Energy Use (kWh/Ton)} - \text{Proposed Energy Use(kWh/Ton)}] \times \text{Cooling Capacity (Tons)} \]

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise, Fo=Continuous

\[ CZ + Fu \times (7.082 \times Tc - 41.199 \times Th + 18.734 \times Ws - 3288.55) + Th \times (0.205 \times Ws - 34.929) \]

\[ 5047.662 + 0 \times (7.082 \times 0 - 41.199 \times 0 + 18.734 \times 168 - 3288.55) + 0 \times (0.205 \times 168 - 34.929) \]

= 5,047.662 kWh/Ton

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise, Fo=Continuous

\[ CZ + Fu \times (7.082 \times Tc - 41.199 \times Th + 18.734 \times Ws - 3288.55) + Th \times (0.205 \times Ws - 34.929) \]

\[ 5047.662 + 1 \times (7.082 \times 10 - 41.199 \times 10 + 18.734 \times 55 - 3288.55) + 10 \times (0.205 \times 55 - 34.929) \]

= 2,211.722 kWh/Ton

\[ \Delta \text{kWh} = [5,047.622 \text{ (kWh/Ton)} - 2,211.722 \text{ (kWh/Ton)}] \times 10 \text{ Tons} \]

= 2,835.89 kWh/Ton * 10 Tons

= 28,358.9 kWh

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

\[ \Delta \text{Therms} = [\text{Baseline Energy Use (Therms/kBtuh)} - \text{Proposed Energy Use(Therms/kBtuh)}] \times \text{Output Heating Capacity (kBtuh)} \]

The following equations are used to calculate baseline and proposed natural gas energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>[ CZ + Fu \times (0.232 \times Th + 0.0984 \times Ws - 18.79) + Th \times (0.00271 \times Ws - 0.535) + 0.0142 \times Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Fu \times (0.00405 \times Th + 0.000519 \times Ws - 0.11) + Th \times (0.0000689 \times Ws - 0.0118) + 0.0022 \times Ws ]</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>[ CZ + Fu \times (0.00545 \times Th - 0.00251 \times Ws + 0.416) + Th \times (0.000123 \times Ws - 0.0204) + 0.00183 \times Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Fu \times (0.00231 \times Th - 0.0349) + Th \times (0.000309 \times Ws - 0.0494) + 0.00266 \times Ws ]</td>
</tr>
<tr>
<td>Office – Low Rise</td>
<td>Continuous</td>
<td>[ CZ + Fu \times (0.0205 \times Th + 0.364) + Th \times (0.00046 \times Ws - 0.0554) + 0.00169 \times Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Fu \times (0.00745 \times Th - 0.142) + Th \times (0.00077 \times Ws - 0.111) + 0.00199 \times Ws ]</td>
</tr>
</tbody>
</table>
### Building Type

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Religious</td>
<td>Continuous</td>
<td>[ CZ + 0.00791^* Fu^* Th + Th^<em>(0.00096^</em> Ws - 0.167) + 0.00184^* Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + 0.00143^* Th - 0.0309 + Th^<em>(0.0008^</em> Ws - 0.134) + 0.00219^* Ws ]</td>
</tr>
<tr>
<td>Restaurant - Fast Food</td>
<td>Continuous</td>
<td>[ CZ + Fu^<em>(0.0431^</em> Th + 0.0424^* Ws - 7.517) + Th^<em>(0.00113^</em> Ws - 0.213) + 0.0119^* Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Fu^<em>(0.0125^</em> Th + 0.0036^* Ws - 0.71) + Th^<em>(0.000329^</em> Ws - 0.0615) + 0.00738^* Ws ]</td>
</tr>
<tr>
<td>Restaurant - Full Service</td>
<td>Continuous</td>
<td>[ CZ + Fu^<em>(0.00445^</em> Th + 0.00207^* Ws - 0.082) + 0.00194^* Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Th^<em>(0.000406^</em> Ws - 0.0611) + 0.00228^* Ws ]</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>Continuous</td>
<td>[ CZ + Fu^<em>(0.00998^</em> Th + 0.00591^* Ws - 0.0812) + 0.00194^* Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Th^<em>(0.000406^</em> Ws - 0.0611) + 0.00228^* Ws ]</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>Continuous</td>
<td>[ CZ + Fu^<em>(0.00383^</em> Th - 0.0656) + Th^<em>(0.000575^</em> Ws - 0.0912) + 0.00249^* Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ + Fu^<em>(0.00383^</em> Th - 0.0656) + Th^<em>(0.000575^</em> Ws - 0.0912) + 0.00249^* Ws ]</td>
</tr>
</tbody>
</table>

Where:

- \( CZ \) = Climate Zone Coefficient
- \( Th \) = Degrees of Heating Setback °F
- \( Fu \) = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)
- \( Fo \) = Fan Mode During Occupied Period (e.g. Fan Mode Set to ‘On’)
- \( Fu \) = Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)
- \( Ws \) = Weekly Hours thermostat is in Occupied mode
- Minimum values depend on Building Type (see table below), maximum value of 168 (24/7)

### Natural Gas Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Climate Zone Coefficient (CZ)</th>
<th>Minimum Ws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>19.872 17.83 15.828 15.282 13.482</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>0.237 0.0989 0.0267 -0.0131 -0.0871</td>
<td></td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>1.493 1.081 0.782 0.544 0.114</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>1.128 0.854 0.619 0.437 0.0854</td>
<td></td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>Continuous</td>
<td>1.718 1.317 0.971 0.739 0.319</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>3.447 3.022 2.503 2.251 1.646</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>5.914 5.368 4.557 4.137 3.246</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>8.383 7.211 6.034 5.767 4.71</td>
<td></td>
</tr>
</tbody>
</table>
Building Type | Fan Mode During Occupied Period (Fo) | Climate Zone Coefficient (CZ) | Minimum Ws
---|---|---|---
Restaurant – Full Service | Intermittent | 1.227 | 0.636 | 0.302 | 0.102 | -0.262 | 117
 | Continuous | 5.247 | 4.484 | 3.753 | 3.465 | 2.627 | 93
 | Intermittent | 0.951 | 0.704 | 0.51 | 0.381 | 0.0746 | 93
Retail – Department Store | Continuous | 4.385 | 3.854 | 3.192 | 2.784 | 1.858 | 93
 | Intermittent | 3.061 | 2.672 | 2.182 | 1.829 | 1.008 | 93
Retail – Strip Mall | Continuous | 3.917 | 3.394 | 2.728 | 2.394 | 1.617 | 93
 | Intermittent | 2.659 | 2.292 | 1.811 | 1.543 | 0.909 | 93

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-PROG-V02-150601**

**REVIEW DEADLINE: 1/1/2022**
4.4.19 Demand Controlled Ventilation

DESCRIPTION

Demand control ventilation (DCV) adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create. DCV is part of a building’s ventilation system control strategy. It may include hardware, software, and controls as an integral part of a building’s ventilation design. Active control of the ventilation system provides the opportunity to reduce heating and cooling energy use.

The primary component is a control sensor to communicate either directly with the economizer or with a central computer. The component is most typically a carbon dioxide (CO2) sensor, occupancy sensor, or turnstile counter. This measure is applicable to multiple building types, and savings are classified by the specific building types defined in the Illinois TRM. This measure is modeled to assume night time set backs are in operation and minimum outside air is being used when the building is unoccupied. Systems that have static louvers or that are open at night will likely have greater savings by using the custom program.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by new CO2 sensors installed on return air systems where no other sensors were previously installed. For heating savings, this measure does not apply to any system with terminal reheat (constant volume or variable air volume). For terminal reheat system a custom savings calculation should be used.

DEFINITION OF BASELINE EQUIPMENT

The base case for this measure is a space with no demand control capability. The current code minimum for outside air (OA) is 17 CFM per occupant (ASHRAE 62.1) which is the value assumed in this measure.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed measure life is 10 years and based on CO2 sensor estimated life. 424

DEEMED MEASURE COST

The deemed measure cost is assumed to be the full cost of installation of a DCV retrofit including sensor cost ($500) and installation ($1000 labor) for a total of $1500. 425

LOADSHAPE

Commercial ventilation C23

COINCIDENCE FACTOR

N/A

424 During the course of conversations with vendors and Building Automation System (BAS) contractors, it was determined that sensors have to be functional for up to 10 years. It is recommended that they are part of a normal preventive maintenance program in which calibration is an important part of extending useful life. Although they are not subject to mechanical failure, they do fall out of tolerance over time.

425 Discussion with vendors
CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

For facilities heated by natural gas,

\[ \Delta k\text{Wh} = \frac{\text{Condition Space}}{1000} \times SF_{\text{cooling}} \]

For facilities heated by heat pumps,

\[ \Delta k\text{Wh} = \frac{\text{Condition Space}}{1000} \times SF_{\text{cooling}} + \frac{\text{Condition Space}}{1000} \times SF_{\text{Heat HP}} \]

For facilities heated by electric resistance,

\[ \Delta k\text{Wh} = \frac{\text{Condition Space}}{1000} \times SF_{\text{cooling}} + \frac{\text{Condition Space}}{1000} \times SF_{\text{Heat ER}} \]

Where:
- Conditioned Space = actual square footage of conditioned space controlled by sensor
- \(SF_{\text{cooling}}\) = Cooling Savings Factor = value in table below based on building type and weather zone
- \(SF_{\text{Heat HP}}\) = Heating Savings factor for facilities heated by Heat Pump (HP) = value in table below based on building type and weather zone
- \(SF_{\text{Heat ER}}\) = Heating Savings factor for facilities heated by Electric Resistance (ER) = value in table below based on building type and weather zone

Saving Factor Tables\(^{426}\)

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Zone 1 (Rockford)</th>
<th>Zone 2 (Chicago)</th>
<th>Zone 3 (Springfield)</th>
<th>Zone 4 (Belleville)</th>
<th>Zone 5 (Marion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office - Low-rise</td>
<td>454</td>
<td>456</td>
<td>460</td>
<td>456</td>
<td>462</td>
</tr>
<tr>
<td>Office - Mid-rise</td>
<td>430</td>
<td>431</td>
<td>432</td>
<td>428</td>
<td>433</td>
</tr>
<tr>
<td>Office - High-rise</td>
<td>448</td>
<td>450</td>
<td>452</td>
<td>449</td>
<td>454</td>
</tr>
<tr>
<td>Religious Building</td>
<td>493</td>
<td>509</td>
<td>573</td>
<td>584</td>
<td>605</td>
</tr>
<tr>
<td>Restaurant</td>
<td>505</td>
<td>515</td>
<td>553</td>
<td>569</td>
<td>581</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>620</td>
<td>625</td>
<td>630</td>
<td>638</td>
<td>642</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>380</td>
<td>376</td>
<td>356</td>
<td>406</td>
<td>407</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>602</td>
<td>603</td>
<td>610</td>
<td>612</td>
<td>614</td>
</tr>
<tr>
<td>Elementary School</td>
<td>317</td>
<td>327</td>
<td>352</td>
<td>352</td>
<td>363</td>
</tr>
<tr>
<td>High School</td>
<td>305</td>
<td>316</td>
<td>340</td>
<td>340</td>
<td>352</td>
</tr>
<tr>
<td>College/University</td>
<td>392</td>
<td>410</td>
<td>434</td>
<td>449</td>
<td>462</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>353</td>
<td>358</td>
<td>379</td>
<td>383</td>
<td>389</td>
</tr>
<tr>
<td>Lodging</td>
<td>576</td>
<td>578</td>
<td>586</td>
<td>588</td>
<td>591</td>
</tr>
</tbody>
</table>

\(^{426}\) The electric energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls.
<table>
<thead>
<tr>
<th>Building Type</th>
<th>SF Cooling (kWh/1000 SqFt)</th>
<th>SF Heat HP (kWh/1000 SqFt)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
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<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
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<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
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<td>Zone 2 (Chicago)</td>
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<td>Zone 1 (Rockford)</td>
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<td></td>
<td>Zone 1 (Rockford)</td>
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<td></td>
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<td>Zone 2 (Chicago)</td>
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<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
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<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
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<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
</tr>
<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
</tr>
<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
</tr>
</tbody>
</table>
For example: 7,500 SqFt of low-rise office space in Chicago with gas heat.

\[
\Delta \text{kWh} = \frac{7,500}{1000} \times 456 \\
= 3,420 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

NA

**NATURAL GAS SAVINGS**

\[
\Delta \text{therms} = \frac{\text{Condition Space}}{1000} \times \text{SF Heat Gas}
\]

Where:

\[\text{SF Heat Gas} = \text{value in table below based on building type and weather zone}\]

<table>
<thead>
<tr>
<th>Building Type</th>
<th>SF Heat Gas (Therm/1000 sq ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 1 (Rockford)</td>
</tr>
<tr>
<td>Office - Low-rise</td>
<td>30</td>
</tr>
<tr>
<td>Office - Mid-rise</td>
<td>20</td>
</tr>
<tr>
<td>Office - High-rise</td>
<td>27</td>
</tr>
<tr>
<td>Religious Building</td>
<td>191</td>
</tr>
<tr>
<td>Restaurant</td>
<td>135</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>47</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>31</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>23</td>
</tr>
<tr>
<td>Elementary School</td>
<td>83</td>
</tr>
<tr>
<td>High School</td>
<td>81</td>
</tr>
<tr>
<td>College/ University</td>
<td>161</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>57</td>
</tr>
<tr>
<td>Lodging</td>
<td>26</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>21</td>
</tr>
<tr>
<td>Special Assembly Auditorium</td>
<td>225</td>
</tr>
<tr>
<td>De-fault</td>
<td>77</td>
</tr>
</tbody>
</table>

For example: 7,500 SqFt of low-rise office space in Chicago.

\[
\Delta \text{Therms} = 7,500 \times 26 \\
= 195 \text{ Therms}
\]

427 The natural gas energy savings was calculated using TMY3 weather data and methodology consistent with ASHRAE standards. Savings are calculated on an annual basis for each given temperature zone in Illinois. Energy savings for DCV were developed utilizing standards, inputs and approaches as set forth by ASHRAE 62.1 and 90.1, respectively. Building input parameters like square footage, equipment efficiencies and occupancy match those used in the EFLH calculations. Reference calculation found in Demand Control Ventilation 12-30-13.xls.
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-DCV-V04-180101

REVIEW DEADLINE: 1/1/2022
4.4.20 High Turndown Burner for Space Heating Boilers

DESCRIPTION

This measure is for a non-residential boilers equipped with linkageless controls providing space heating with burners having a turndown less than 6:1. Turndown is the ratio of the high firing rate to the low firing rate. When boilers are subjected to loads below the low firing rate, the boiler must cycle on/off to meet the load requirements. A higher turndown ratio reduces burner startups, provides better load control, saves wear-and-tear on the burner, and reduces purge-air requirements, all of these benefits result in better overall efficiency.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler linkageless burner must operate with a turndown greater than or equal to 10:1 and be subjected to loads less than or equal to 30% of the full fire input MBH for greater than 60% of the operating hours.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler utilizes a linkageless burner with a turndown ration of 6:1 or less and is used primarily for space heating. Redundant boilers do not qualify.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 21 years.

DEEMED MEASURE COST

The deemed installed measure cost including labor is approximately $2.53/MBtu/hr.

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

---

429 Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, March 22, 2010. This factor implies that boilers are 30% oversized on average.
430 FES Analysis of bin hours based upon a 30% oversizing factor.
432 FES review of PY2/PY3 costs for custom People’s and North Shore high turndown burner projects. See High Turndown Costs.xlsx for details.
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

\[ \Delta \text{therms} = \text{Ngi} \times \text{SF} \times \text{EFLH} / 100 \]

Where:

- \( \text{Ngi} \) = Boiler gas input size (kBtu/hr) = custom
- \( \text{SF} \) = Savings Factor = Percentage of energy loss per hour
  \[ = \left( \sum (\text{EL}_{\text{base}} - \text{EL}_{\text{eff}}) \times \text{H}_{\text{cycling}} \right) / \text{H} \]  
  Where:
  - \( \text{EL}_{\text{base}} \) = Base Boiler Percentage of energy loss due to cycling at % of Base Boiler Load where \( \text{BL}_{\text{base}} \leq \text{TDR}_{\text{base}} \)
    \[ = 0.003 \times (\text{Cycles}_{\text{base}})^2 - 0.001 \times \text{Cycles}_{\text{base}} \]  
    Where:
    - \( \text{Cycles}_{\text{base}} \) = Number of Cycles/hour of base boiler
      \[ = \frac{\text{TDR}_{\text{base}}}{\text{BL}} \]  
    Where:
    - \( \text{BL} \) = % of full boiler load at bin hours being evaluated. This is assumed to be a straight line based on 0% load at the building balance point (assumed to be 55F), and full load corrected for the oversizing (OSF) at the lowest temperature bin of -10 to -5F.
    - \( \text{OSF} \) = Oversizing Factor = 1.3 or custom
      \[ \text{TDR}_{\text{base}} = \text{Turndown ratio} = 0.33 \]  
    - \( \text{EL}_{\text{eff}} \) = Efficient Boiler Percentage of energy loss due to cycling at % of Efficient Boiler Load
      \[ = 0.003 \times (\text{Cycles}_{\text{eff}})^2 - 0.001 \times \text{Cycles}_{\text{eff}} \]  
    Where:
    - \( \text{Cycles}_{\text{eff}} \) = Number of Cycles/hour

435 Ibid.
= TDR_{eff} / BL

Where:

\[
TDR_{eff} = \text{Turndown ratio} = 0.10^{436} \text{ or custom}
\]

\[
H_{cycling} = \text{Hours base boiler is cycling at } \% \text{ of base boiler load}
\]

= see table below or custom

\[
H = \text{Total Number of Hours in Heating Season}
\]

= 4,946 or custom

100 = convert to a percentage

\[
SF = \frac{69.1}{4946} \times 100 = 1.4\% \text{ or custom (see table below for summary of values)}
\]

<table>
<thead>
<tr>
<th>Temperature</th>
<th>H_{cycling}</th>
<th>BL</th>
<th>EL_{base}</th>
<th>EL_{eff}</th>
<th>(EL_{base} - EL_{eff}) \times \text{Hours}</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 to 55</td>
<td>601</td>
<td>6.0%</td>
<td>8.5%</td>
<td>0.7%</td>
<td>47.2</td>
</tr>
<tr>
<td>45 to 50</td>
<td>603</td>
<td>12.0%</td>
<td>2.0%</td>
<td>0.0%</td>
<td>12.0</td>
</tr>
<tr>
<td>40 to 45</td>
<td>455</td>
<td>18.0%</td>
<td>0.8%</td>
<td>0.0%</td>
<td>3.8</td>
</tr>
<tr>
<td>35 to 40</td>
<td>925</td>
<td>24.0%</td>
<td>0.4%</td>
<td>0.0%</td>
<td>4.0</td>
</tr>
<tr>
<td>30 to 35</td>
<td>814</td>
<td>30.0%</td>
<td>0.3%</td>
<td>0.0%</td>
<td>2.1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69.1</td>
</tr>
</tbody>
</table>

EFLH = \text{Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use.}

100 = convert kBtu to therms

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code:** CI-HVAC-HTBC-V04-140601

**Review Deadline:** 1/1/2020

---

^{436} 10:1 ratio used to qualify for efficient equipment.
4.4.21 Linkageless Boiler Controls for Space Heating

DESCRIPTION

This measure is for a non-residential boiler providing space heating and currently having single point positioning combustion control. In single-point positioning control, the fuel valve is linked to the combustion air damper via a jackshaft mechanism to maintain correspondence between fuel and combustion air input. Most boilers with single point positioning control do not maintain low excess air levels over their entire firing range. Generally these boilers are calibrated at high fire, but due to the non-linearity required for efficient combustion, excess air levels tend to dramatically increase as the firing rate decreases. Boiler efficiency drops as the excess air levels are increased.

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify the boiler burner must have a linkageless control system allowing the combustion air damper position to be adjusted and set for optimal efficiency at several firing rates throughout the burner’s firing range. This requires the fuel valve and combustion air damper to each be powered by a separate actuator. An alternative to the combustion air damper is a Variable Speed Drive on the combustion air fan.

DEFINITION OF BASELINE EQUIPMENT

The baseline boiler utilizes single point positioning for the burner combustion control.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 16 years.437

DEEMED MEASURE COST

The deemed measure cost is estimated at $2.50/MBtu/hr burner input.438

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Calculation of Savings

Electric Energy Savings

When a Variable Speed Drive is incorporated, electrical savings are calculated according to the “4.4.17 Variable Speed Drive for HVAC Pumps and Cooling Tower Fans” measure.

437 Total number of hours for heating with a base temperature of 55°F for Chicago, IL as noted by National Climate Data Center
SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS SAVINGS

\[ \Delta \text{Therms} = \frac{\text{Ngi} \times \text{SF} \times \text{EFLH}}{100} \]

Where:

- \text{Ngi} = \text{Boiler gas input size (kBtu/hr)} = \text{custom}
- \text{SF} = \text{Savings factor}

Note: Savings factor is the percentage increase in efficiency as a result of the addition of linkageless burner controls. At an average boiler load of 35%, single point controls are assumed to have excess air of 91%, while linkageless controls are assumed to have 34% excess air.\footnote{Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from Industrial, Commercial, and Institutional Boilers, Prepared by the Sector Policies and Programs Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711, October 2010, Table 1. ICI Boilers – Summary of Greenhouse Gas Emission Reduction Measures, pg. 8} The difference between controls types is 57% at this average operating condition. A 15% reduction in excess air is approximately a 1% increase in efficiency.\footnote{Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improve Your Boiler’s Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated.} Therefore the nominal combustion efficiency increase is \( \frac{57}{15} \times 1\% = 3.8\% \).

\[ = 3.8\% \]

- \text{EFLH} = \text{Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use}
- \text{100} = \text{convert kBtu to therms}

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-LBC-V05-160601

REVIEW DEADLINE: 1/1/2022
4.4.22 Oxygen Trim Controls for Space Heating Boilers

DESCRIPTION
This measure is for a non-residential boiler providing space heating without oxygen trim combustion controls. Oxygen trim controls limit the amount of excess oxygen provided to the burner for combustion. This oxygen level is dependent upon the amount of air provided. Oxygen trim control converts parallel positioning, linkageless controls, into a closed-loop control configuration with the addition of an exhaust gas analyzer and PID controller. Boilers with oxygen trim controls can maintain a predetermined excess air rate (generally 15% to 30% excess air) over the entire burner firing rate. Boilers without these controls typically have excess air rates around 30% over the entire firing rate. Boiler efficiency drops as the excess air levels are increased.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify the boiler burner must have an oxygen control system allowing the combustion air to be adjusted to maintain a predetermined excess oxygen level in the flue exhaust at all firing rates throughout the burner’s firing range. This requires an oxygen sensor in the flue exhaust and linkageless fuel valve and combustion air controls.

DEFINITION OF BASELINE EQUIPMENT
The baseline boiler utilizes single point positioning for the burner combustion control.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The measure life for the O2 Trim controls is 18 years.\textsuperscript{441}

DEEMED MEASURE COST
The deemed measure cost is approximately $23,250.\textsuperscript{442}

LOADSHAPE
N/A

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS
N/A


\textsuperscript{442} CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22
SUMMER COINCIDENT PEAK DEMAND SAVINGS
N/A

NATURAL GAS ENERGY SAVINGS

$$\Delta \text{Therms} = \frac{\text{Ngi} \times \text{SF} \times \text{EFLH}}{100}$$

Where:

- **Ngi** = Boiler gas input size (kBtu/hr)
- **SF** = Savings factor
- **EFLH** = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

Note: Savings factor is the percentage reduction in gas consumption as a result of the addition of O2 trim controls. Linkageless controls have an excess air rate of 28% over the entire firing range. O2 trim controls have an excess air rate of 15%. The average difference is 13%. A 15% reduction in excess air is approximately a 1% increase in efficiency. Therefore the nominal combustion efficiency increase is 13 / 15 * 1% = 0.87%.

- **EFLH** = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The deemed annual Operations and Maintenance cost is $800.

MEASURE CODE: CI-HVC-O2TC-V01-140601

REVIEW DEADLINE: 1/1/2022

---


444 Ibid

446 Department of Energy (DOE). January 2012, Steam Tip Sheet #4, Improving Your Boiler’s Combustion Efficiency. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. This value was determined as an appropriate average over the stack temperatures and excess air levels indicated.
4.4.23 Shut Off Damper for Space Heating Boilers or Furnaces

**DESCRIPTION**

This measure is for non-residential atmospheric boilers or furnaces providing space heating without a shut off damper. When appliances are on standby mode warm room air is drawn through the stack via the draft hood or dilution air inlet at a rate proportional to the stack height, diameter and outdoor temperature. More air is drawn through the vent immediately after the appliance shuts off and the flue is still hot. Installation of a new shut off damper can prevent heat from being drawn up the warm vent and reducing the amount of air that passes through the furnace or boiler heat exchanger. This reduction in air can slightly increase overall operating efficiency by reducing the time needed to achieve steady-state operating conditions.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify the space heating boiler or furnace must have a new electrically or thermally activated shut off damper installed on either the exhaust flue or combustion air intake. Barometric dampers do not qualify. The damper actuation shall be interlocked with the firing controls.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline boiler or furnace incorporates no shut off damper on the combustion air intake or flue exhaust.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the shut off damper is 15 years.\(^{447}\)

**DEEMED MEASURE COST**

The deemed measure cost for this approximately $1,500.\(^{448}\)

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A


\(^{448}\) CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22
**SUMMER COINCIDENT PEAK DemAND SAVINGS**

N/A

**NATURAL GAS ENERGY SAVINGS**

\[
\Delta \text{Therms} = \frac{\text{Ngi} \times \text{SF} \times \text{EFLH}}{100}
\]

Where:

- \(\text{Ngi}\) = Boiler gas input size (kBtu/hr)
- \(\text{SF}\) = Savings factor
- \(\text{EFLH}\) = Default Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use. When available, actual hours should be used.
- \(\text{EFLH}\) = convert kBtu to therms

Note: The savings factor assumes the boiler or furnace is located in an unconditioned space. The savings factor can be higher for those units located within conditioned space.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The deemed annual Operations and Maintenance cost is $112.\(^{450}\)

**MEASURE CODE: CI-HVC-SODP-V01-140601**

**REVIEW DEADLINE: 1/1/2020**

---

\(^{449}\) Based on internet review of savings potential;


“Up to 1%”: Page 9, The Carbon Trust, “Steam and high temperature hot water boilers”

http://www.carbontrust.com/media/13332/ctv052_steam_and_high_temperature_hot_water_boilers.pdf

“1 - 2%”: Page 2, Sustainable Energy Authority of Ireland “Steam Systems Technical Guide”;


\(^{450}\) CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE) PROCESS BOILERS, 2013 California Building Energy Efficiency Standards, California Utilities Statewide Codes and Standards Team, October 2011, pg. 22
4.4.24 Small Pipe Insulation

**DESCRIPTION**

This measure provides rebates for adding insulation to bare pipes with inner diameters of ½” and ¾”. Insulation must be at least one inch thick. Since new construction projects are required by code to have pipe insulation, this measure is only for retrofits of existing facilities. This covers bare straight pipe as well as all fittings.

Default savings are provided on a per linear foot basis. It is assumed that the majority of pipes less than one inch in commercial facilities are used for domestic hot water. However, this measure can cover hydronic heating systems as well as low and high pressure steam systems.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient case is a ½” or ¾” diameter pipe with at least one inch of insulation. Insulation must be protected from damage which includes moisture, sunlight, equipment maintenance and wind. Outdoor pipes should have a weather protective jacket. Insulation must be continuous over straight pipe, elbows and tees.

**DEFINITION OF BASELINE EQUIPMENT**

The base case for savings estimates is a bare hot water or steam pipe with a fluid temperature of 105 degrees Fahrenheit or greater. Current new construction code requires insulation amounts similar to this measure though this base case is commonly found in older existing buildings.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 15 years.\(^{451}\)

**DEEMED MEASURE COST**

The incremental measure cost for insulation is the full cost of adding insulation to the pipe. Actual installation costs should be used for the measure cost. For planning purposes, the following costs can be used to estimate the full cost of materials and labor.\(^{452}\)

<table>
<thead>
<tr>
<th>Insulation Thickness</th>
<th>¾” pipe</th>
<th>½” pipe</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td>$4.45</td>
<td>$4.15</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A


\(^{452}\) A market survey was performed to determine these costs.
Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

\[ \Delta \text{Therms per foot}^{453} = \left( (Q_{\text{base}} - Q_{\text{eff}}) \times EFLH \right) / \left( 100,000 \times \eta_{\text{Boiler}} \right) \times TRF \]

\[ = \left( \text{Modeled or provided by tables below} \right) \times TRF \]

\[ \Delta \text{Therms} = (L_{\text{sp}} + L_{\text{loc}}) \times \Delta \text{therms per foot} \]

Where:

- **EFLH** = Equivalent Full Load Hours for Heating
  = Actual or defaults by building type provided in Section 4.4, HVAC end use
  
  For year round recirculation or domestic hot water:
  \[ = 8,766 \]
  
  For heating season recirculation, hours with the outside air temperature below 55°F:
  
<table>
<thead>
<tr>
<th>Zone</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 (Rockford)</td>
<td>5,039</td>
</tr>
<tr>
<td>Zone 2 (Chicago)</td>
<td>4,963</td>
</tr>
<tr>
<td>Zone 3 (Springfield)</td>
<td>4,495</td>
</tr>
<tr>
<td>Zone 4 (Belleville/)</td>
<td>4,021</td>
</tr>
<tr>
<td>Zone 5 (Marion)</td>
<td>4,150</td>
</tr>
</tbody>
</table>

- **Q_{\text{base}}** = Heat Loss from Bare Pipe (Btu/hr/ft)
  = Calculated where possible using 3E Plusv4.0 software. For defaults see table below

- **Q_{\text{eff}}** = Heat Loss from Insulated Pipe (Btu/hr/ft)
  = Calculated where possible using 3E Plusv4.0 software. For defaults see table below

- **100,000** = conversion factor (1 therm = 100,000 Btu)

- **\eta_{\text{Boiler}}** = Efficiency of the boiler being used to generate the hot water or steam in the pipe
  \[ = 81.9\% \text{ for water boilers}^{454} \]
  \[ = 80.7\% \text{ for steam boilers, except multifamily low-pressure}^{455} \]

---

453 This value comes from the reference table “Savings Summary by Building Type and System Type.” The formula and the input tables in this section document assumptions used in calculation spreadsheet “Pipe Insulation Savings 2013-11-12.xlsx”

454 Average efficiencies of units from the California Energy Commission (CEC).

455 Ibid.
= 64.8% for multifamily low-pressure steam boilers

TRF = Thermal Regain Factor for space type, applied only to space heating energy and is applied to values resulting from Δtherms/ft tables below

= See table below for base TRF values by pipe location

May vary seasonally such as: TRF[summer] * summer hours + TRF[winter] * winter hours where TRF values reflecting summer and winter conditions are apportioned by the hours for those conditions. TRF may also be adjusted by building specific balance temperature and operating hours above and below that balance temperature.

<table>
<thead>
<tr>
<th>Pipe Location</th>
<th>Assumed Regain</th>
<th>TRF, Thermal Regain Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor</td>
<td>0%</td>
<td>1.0</td>
</tr>
<tr>
<td>Indoor, heated space</td>
<td>85%</td>
<td>0.15</td>
</tr>
<tr>
<td>Indoor, semi-heated, (unconditioned space, with heat transfer to conditioned space. E.g.: boiler room, ceiling plenum, basement, crawlspace, wall)</td>
<td>30%</td>
<td>0.70</td>
</tr>
<tr>
<td>Indoor, unheated, (no heat transfer to conditioned space)</td>
<td>0%</td>
<td>1.0</td>
</tr>
<tr>
<td>Location not specified</td>
<td>85%</td>
<td>0.15</td>
</tr>
<tr>
<td>Custom</td>
<td>Custom</td>
<td>1 – assumed regain</td>
</tr>
</tbody>
</table>

$L_{sp}$ = Length of straight pipe to be insulated (linear foot)

$L_{eq,i}$ = Total equivalent length of (elbows and tees) of pipe to be insulated. Use table below to determine equivalent lengths.

<table>
<thead>
<tr>
<th>Nominal Pipe Diameter</th>
<th>Equivalent Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90 Degree Elbow</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>0.04</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>0.06</td>
</tr>
</tbody>
</table>

The table below shows the deemed therm savings by building type and region on a per linear foot basis for both ½" and ¾" copper pipe.

The following table provides deemed values for 1/2" copper pipe, temperatures are assumed by category below, and insulation is assumed to be one inch fiberglass.

---


457 Thermal regain for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012 and Andrews, John, Better Duct Systems for Home Heating and Cooling, U.S. Department of Energy, 2001. Recognizing the differences between residential and commercial heating systems, the factors have been adjusted based on professional judgment. This factor would benefit from additional study and evaluation.

458 Thermal Regain Factor_4-30-14.docx

### Small Pipe Insulation

<table>
<thead>
<tr>
<th>Piping Use</th>
<th>Building Type</th>
<th>Annual Therm Saved / Linear Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Zone 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Rockford)</td>
</tr>
<tr>
<td>Space Heating</td>
<td>Assembly</td>
<td>0.117</td>
</tr>
<tr>
<td>Non-recirculating</td>
<td>Assisted Living</td>
<td>0.110</td>
</tr>
<tr>
<td></td>
<td>College</td>
<td>0.100</td>
</tr>
<tr>
<td></td>
<td>Convenience Store</td>
<td>0.097</td>
</tr>
<tr>
<td></td>
<td>Elementary School</td>
<td>0.116</td>
</tr>
<tr>
<td></td>
<td>Garage</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>Grocery</td>
<td>0.105</td>
</tr>
<tr>
<td></td>
<td>Healthcare Clinic</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>High School</td>
<td>0.120</td>
</tr>
<tr>
<td></td>
<td>Hospital - CAV no econ</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>Hospital - CAV econ</td>
<td>0.117</td>
</tr>
<tr>
<td></td>
<td>Hospital - VAV econ</td>
<td>0.048</td>
</tr>
<tr>
<td></td>
<td>Hospital - FCU</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>Hotel/Motel</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>Hotel/Motel - Common</td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>Hotel/Motel - Guest</td>
<td>0.115</td>
</tr>
<tr>
<td></td>
<td>Manufacturing Facility</td>
<td>0.068</td>
</tr>
<tr>
<td></td>
<td>MF - High Rise</td>
<td>0.100</td>
</tr>
<tr>
<td></td>
<td>MF - High Rise - Common</td>
<td>0.118</td>
</tr>
<tr>
<td></td>
<td>MF - High Rise - Residential</td>
<td>0.096</td>
</tr>
<tr>
<td></td>
<td>MF - Mid Rise</td>
<td>0.109</td>
</tr>
<tr>
<td></td>
<td>Movie Theater</td>
<td>0.119</td>
</tr>
<tr>
<td></td>
<td>Office - High Rise - CAV no econ</td>
<td>0.132</td>
</tr>
<tr>
<td></td>
<td>Office - High Rise - CAV econ</td>
<td>0.136</td>
</tr>
<tr>
<td></td>
<td>Office - High Rise - VAV econ</td>
<td>0.100</td>
</tr>
<tr>
<td></td>
<td>Office - High Rise - FCU</td>
<td>0.073</td>
</tr>
<tr>
<td></td>
<td>Office - Low Rise</td>
<td>0.093</td>
</tr>
<tr>
<td></td>
<td>Office - Mid Rise</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>Religious Building</td>
<td>0.105</td>
</tr>
<tr>
<td></td>
<td>Restaurant</td>
<td>0.088</td>
</tr>
<tr>
<td></td>
<td>Retail - Department Store</td>
<td>0.091</td>
</tr>
<tr>
<td></td>
<td>Retail - Strip Mall</td>
<td>0.087</td>
</tr>
<tr>
<td></td>
<td>Warehouse</td>
<td>0.095</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>0.101</td>
</tr>
<tr>
<td>Space Heating</td>
<td>All buildings (Hours below 55°F)</td>
<td>0.329</td>
</tr>
<tr>
<td>recirculation</td>
<td>heating season only</td>
<td></td>
</tr>
<tr>
<td>season only</td>
<td>All buildings (All hours)</td>
<td>0.572</td>
</tr>
<tr>
<td>DHW</td>
<td>Recirculation loop</td>
<td>0.572</td>
</tr>
<tr>
<td>Process</td>
<td>Custom</td>
<td></td>
</tr>
</tbody>
</table>

### Extra Information

- **Space Heating**
  - **Non-recirculating**
  - **Space Heating - recirculation**
    - **heating season only**
    - **Space Heating - recirculation**
      - **year round**

- **DHW**
  - **Recirculation loop**
  - **Process**
    - **Custom**
The following table provides deemed savings values for 3/4” copper pipe with temperatures assumed by category below, insulation is assumed to be one inch fiberglass.

<table>
<thead>
<tr>
<th>Piping Use</th>
<th>Building Type</th>
<th>Annual Therms Saved / Linear Foot</th>
<th>Zone 1 (Rockford)</th>
<th>Zone 2 (Chicago)</th>
<th>Zone 3 (Springfield)</th>
<th>Zone 4 (Belleville)</th>
<th>Zone 5 (Marion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td></td>
<td></td>
<td>0.142</td>
<td>0.145</td>
<td>0.129</td>
<td>0.086</td>
<td>0.132</td>
</tr>
<tr>
<td>Assisted Living</td>
<td></td>
<td></td>
<td>0.133</td>
<td>0.130</td>
<td>0.115</td>
<td>0.084</td>
<td>0.101</td>
</tr>
<tr>
<td>College</td>
<td></td>
<td></td>
<td>0.121</td>
<td>0.113</td>
<td>0.101</td>
<td>0.056</td>
<td>0.067</td>
</tr>
<tr>
<td>Convenience Store</td>
<td></td>
<td></td>
<td>0.117</td>
<td>0.108</td>
<td>0.096</td>
<td>0.069</td>
<td>0.077</td>
</tr>
<tr>
<td>Elementary School</td>
<td></td>
<td></td>
<td>0.141</td>
<td>0.137</td>
<td>0.121</td>
<td>0.084</td>
<td>0.102</td>
</tr>
<tr>
<td>Garage</td>
<td></td>
<td></td>
<td>0.078</td>
<td>0.077</td>
<td>0.067</td>
<td>0.054</td>
<td>0.060</td>
</tr>
<tr>
<td>Grocery</td>
<td></td>
<td></td>
<td>0.127</td>
<td>0.127</td>
<td>0.111</td>
<td>0.069</td>
<td>0.083</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td></td>
<td></td>
<td>0.125</td>
<td>0.128</td>
<td>0.112</td>
<td>0.076</td>
<td>0.081</td>
</tr>
<tr>
<td>High School</td>
<td></td>
<td></td>
<td>0.146</td>
<td>0.147</td>
<td>0.132</td>
<td>0.094</td>
<td>0.110</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td></td>
<td></td>
<td>0.140</td>
<td>0.144</td>
<td>0.123</td>
<td>0.105</td>
<td>0.120</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td></td>
<td></td>
<td>0.142</td>
<td>0.147</td>
<td>0.125</td>
<td>0.108</td>
<td>0.123</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td></td>
<td></td>
<td>0.058</td>
<td>0.055</td>
<td>0.041</td>
<td>0.025</td>
<td>0.027</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td></td>
<td></td>
<td>0.105</td>
<td>0.120</td>
<td>0.098</td>
<td>0.115</td>
<td>0.154</td>
</tr>
<tr>
<td>Hotel/Motel</td>
<td></td>
<td></td>
<td>0.140</td>
<td>0.136</td>
<td>0.122</td>
<td>0.084</td>
<td>0.102</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td></td>
<td></td>
<td>0.127</td>
<td>0.129</td>
<td>0.123</td>
<td>0.100</td>
<td>0.105</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td></td>
<td></td>
<td>0.139</td>
<td>0.135</td>
<td>0.120</td>
<td>0.081</td>
<td>0.099</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td></td>
<td></td>
<td>0.083</td>
<td>0.080</td>
<td>0.074</td>
<td>0.045</td>
<td>0.050</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td></td>
<td></td>
<td>0.121</td>
<td>0.119</td>
<td>0.109</td>
<td>0.093</td>
<td>0.093</td>
</tr>
<tr>
<td>MF - High Rise - Common</td>
<td></td>
<td></td>
<td>0.144</td>
<td>0.140</td>
<td>0.125</td>
<td>0.086</td>
<td>0.111</td>
</tr>
<tr>
<td>MF - High Rise - Residential</td>
<td></td>
<td></td>
<td>0.117</td>
<td>0.116</td>
<td>0.105</td>
<td>0.091</td>
<td>0.089</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td></td>
<td></td>
<td>0.132</td>
<td>0.134</td>
<td>0.115</td>
<td>0.085</td>
<td>0.096</td>
</tr>
<tr>
<td>Movie Theater</td>
<td></td>
<td></td>
<td>0.144</td>
<td>0.142</td>
<td>0.133</td>
<td>0.101</td>
<td>0.120</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td></td>
<td></td>
<td>0.160</td>
<td>0.162</td>
<td>0.148</td>
<td>0.099</td>
<td>0.108</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td></td>
<td></td>
<td>0.165</td>
<td>0.169</td>
<td>0.155</td>
<td>0.107</td>
<td>0.118</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td></td>
<td></td>
<td>0.121</td>
<td>0.123</td>
<td>0.102</td>
<td>0.060</td>
<td>0.067</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td></td>
<td></td>
<td>0.089</td>
<td>0.087</td>
<td>0.075</td>
<td>0.040</td>
<td>0.042</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td></td>
<td></td>
<td>0.113</td>
<td>0.113</td>
<td>0.090</td>
<td>0.055</td>
<td>0.063</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td></td>
<td></td>
<td>0.126</td>
<td>0.126</td>
<td>0.106</td>
<td>0.068</td>
<td>0.075</td>
</tr>
<tr>
<td>Religious Building</td>
<td></td>
<td></td>
<td>0.127</td>
<td>0.119</td>
<td>0.114</td>
<td>0.084</td>
<td>0.095</td>
</tr>
<tr>
<td>Restaurant</td>
<td></td>
<td></td>
<td>0.107</td>
<td>0.107</td>
<td>0.096</td>
<td>0.073</td>
<td>0.086</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td></td>
<td></td>
<td>0.110</td>
<td>0.101</td>
<td>0.095</td>
<td>0.062</td>
<td>0.071</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td></td>
<td></td>
<td>0.106</td>
<td>0.098</td>
<td>0.086</td>
<td>0.059</td>
<td>0.064</td>
</tr>
<tr>
<td>Warehouse</td>
<td></td>
<td></td>
<td>0.115</td>
<td>0.108</td>
<td>0.111</td>
<td>0.069</td>
<td>0.085</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td></td>
<td>0.123</td>
<td>0.122</td>
<td>0.108</td>
<td>0.078</td>
<td>0.090</td>
</tr>
<tr>
<td>Piping Use</td>
<td>Building Type</td>
<td>Zone 1 (Rockford)</td>
<td>Zone 2 (Chicago)</td>
<td>Zone 3 (Springfield)</td>
<td>Zone 4 (Belleville)</td>
<td>Zone 5 (Marion)</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>----------------------------------------</td>
<td>-------------------</td>
<td>------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>Space Heating - recirculation</td>
<td>All buildings (Hours below 55°F)</td>
<td>0.399</td>
<td>0.393</td>
<td>0.356</td>
<td>0.319</td>
<td>0.329</td>
<td></td>
</tr>
<tr>
<td>heating season only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Space Heating - recirculation</td>
<td>All buildings (All hours)</td>
<td>0.694</td>
<td>0.694</td>
<td>0.694</td>
<td>0.694</td>
<td>0.694</td>
<td></td>
</tr>
<tr>
<td>year round</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DHW</td>
<td>Recirculation loop</td>
<td>0.694</td>
<td>0.694</td>
<td>0.694</td>
<td>0.694</td>
<td>0.694</td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>Custom</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-SPIN-V02-160601**

**REVIEW DEADLINE: 1/1/2023**
4.4.25 Small Commercial Programmable Thermostat Adjustments

**DESCRIPTION**

This measure involves reprogramming existing commercial programmable thermostats or building automation systems for reduced energy consumption through adjustments of unoccupied heating/cooling setpoints and/or fan control. This measure is limited to packaged HVAC units that are controlled by a commercial thermostat or building automation system. The measure is limited to select building types presented below.

<table>
<thead>
<tr>
<th>Eligible Small Commercial Building Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Type</td>
</tr>
<tr>
<td>Assembly</td>
</tr>
<tr>
<td>Convenience Store</td>
</tr>
<tr>
<td>Office - Low Rise</td>
</tr>
<tr>
<td>Restaurant - Fast Food</td>
</tr>
<tr>
<td>Religious Facility</td>
</tr>
<tr>
<td>Restaurant - Full Service</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
</tr>
<tr>
<td>Retail - Department Store</td>
</tr>
</tbody>
</table>

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The criteria for this measure is established by optimizing heating/cooling temperature setbacks and fan operation with a commercial programmable thermostat or building automation system, which reprogrammed to match actual facility occupancy.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline for this measure is a commercial programmable thermostat or building automation system that is currently operating packaged HVAC units with heating/cooling temperature setbacks and fan operation that do not align with a facilities actual occupancy.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life of a programmable thermostat is assumed to be 8 years\(^{459}\) based upon equipment life only\(^{460}\). For the purposes of claiming savings for a adjustment of an existing programmable thermostat, this is reduced to a 25% persistence factor to give a final measure life of 2 years. It is recommended that this assumption be evaluated by future energy measurement and verification activities.

**DEEMED MEASURE COST**

Actual labor costs should be used if the implementation method allows. If unknown the labor cost for this measure is assumed to be $70.34\(^{461}\) per thermostat, as summarized in the table below.

---

\(^{459}\)Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

\(^{460}\)Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption.

Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta kW = \text{[Baseline Energy Use (kWh/Ton) – Proposed Energy Use (kWh/Ton)]} \times \text{Cooling Capacity (Tons)} \]

The following equations are used to calculate baseline and proposed electric energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Electric Energy Use Equations (kWh / ton)**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>[ CZ+Fu^*[(0.83^*Tc+0.83^*Th+1.67^*Ws-293.018)-0.0922^*Tc^*Th+1.291^*Ws] ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ+Fu^*[1.911-0.12^<em>Tc]+Tc^</em>[(0.00311^*Ws-0.229)+0.11^*Ws] ]</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>[ CZ+Fu^*(-28.629^*Tc-11.69^*Th+19.118^*Ws-2935.12)+0.909^*Ws ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ+Tc^*(0.0863^<em>Ws-12.688)+Th^</em>(0.043^*Ws-6.38)+1.669^*Ws ]</td>
</tr>
<tr>
<td>Office – Low Rise</td>
<td>Continuous</td>
<td>[ CZ+Fu^*(7.082^*Tc-41.199^*Th+18.734^<em>Ws-3288.55)+Tc^</em>(0.205^*Ws-34.929) ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ+Tc^*(0.0806^<em>Ws-8.984)+Th^</em>(0.0864^*Ws-9.558)+1.178^*Ws ]</td>
</tr>
<tr>
<td>Religious</td>
<td>Continuous</td>
<td>[ CZ+Fu^*(-1.579^*Tc-18.14^*Th+15.01^<em>Ws-2417.74)+Tc^</em>(0.177^*Ws-26.412) ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ+Fu^*(0.266^<em>Tc-2.067)+Tc^</em>[(0.0295^<em>Ws-4.502)+Th^</em>(0.0517^*Ws-8.251)+0.735^*Ws] ]</td>
</tr>
<tr>
<td>Restaurant – Fast Food</td>
<td>Continuous</td>
<td>[ CZ+Fu^*(0.678^*Tc+0.257^*Th+2.88^<em>Ws-494.006)+Tc^</em>(0.0231^<em>Ws-4.074)+Th^</em>[(0.0036^*Ws-1.655)+0.918^*Ws] ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ+Fu^*(0.377^*Tc-0.124^*Th+0.13^<em>Ws-24.893)+Tc^</em>(-0.0143^*Th+0.0166^*Ws-2.691)+0.898^*Ws] ]</td>
</tr>
<tr>
<td>Restaurant – Sit Down</td>
<td>Continuous</td>
<td>[ CZ+Fu^*(-8.41^*Th+11.766^<em>Ws-1910.81)+Tc^</em>(0.282^*Ws-43.851) ]</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>[ CZ+0.123^<em>Fu^</em>+Tc^*[(0.0561^<em>Ws-8.237)+Th^</em>(0.0219^*Ws-3.284)+1.038^*Ws] ]</td>
</tr>
<tr>
<td>Retail – Large</td>
<td>Continuous</td>
<td>[ CZ+Fu^*(-1.475^*Th+0.755^<em>Ws-114.373)+Th^</em>[0.151^*Ws-24.016]+1.612^*Ws ]</td>
</tr>
</tbody>
</table>

### 4.4.25 Small Commercial Programmable Thermostat Adjustments

**Equation**

\[ 
\text{Retail – Strip Mall} = \begin{cases} 
\text{Continuous} & \text{CZ} + Tc \left( Ws \cdot 0.0173 \right) + Th \left( Ws \cdot 0.0249 \right) + 0.511 \times Ws \\
\text{Intermittent} & \text{CZ} + Tc \left( Ws \cdot 0.0894 \right) + Th \left( Ws \cdot 0.0142 \right) + 0.884 \times Ws 
\end{cases} 
\]

Where:

- **CZ** = Climate Zone Coefficient
  - Depends on Building Type and Fan Mode During Occupied Period (see table below)
- **Tc** = Degrees of Cooling Setback °F
  - Must be between 0-15°F
- **Th** = Degrees of Heating Setback °F
  - Must be between 0-15°F
- **Fo** = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)
  - Continuous for occupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)
  - Intermittent for occupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)
- **Fu** = Fan Mode during Unoccupied Period
  - 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)
  - 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)
- **Ws** = Weekly Hours thermostat is in Occupied mode,
  - Minimum values depend on Building Type (see table below), maximum value of 168 (24/7)
  - ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59

### Electric Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Climate Zone Coefficient (CZ)</th>
<th>Minimum Ws</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Assembly</strong></td>
<td>Continuous</td>
<td>911.366</td>
<td>928.924</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>735.752</td>
<td>762.831</td>
</tr>
<tr>
<td><strong>Convenience Store</strong></td>
<td>Continuous</td>
<td>4817.094</td>
<td>4832.784</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>1478.133</td>
<td>1514.568</td>
</tr>
<tr>
<td><strong>Office - Low Rise</strong></td>
<td>Continuous</td>
<td>5047.662</td>
<td>5039.592</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>825.072</td>
<td>808.965</td>
</tr>
<tr>
<td><strong>Religious Facility</strong></td>
<td>Continuous</td>
<td>4197.117</td>
<td>4172.858</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>632.404</td>
<td>603.395</td>
</tr>
<tr>
<td><strong>Restaurant - Fast Food</strong></td>
<td>Continuous</td>
<td>1342.988</td>
<td>1378.661</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>993.764</td>
<td>1039.643</td>
</tr>
<tr>
<td><strong>Restaurant - Full Service</strong></td>
<td>Continuous</td>
<td>4070.35</td>
<td>4094.742</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>1472.014</td>
<td>1516.05</td>
</tr>
<tr>
<td></td>
<td>Continuous</td>
<td>1510.201</td>
<td>1496.47</td>
</tr>
</tbody>
</table>
EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and is heated and cooled with a packaged Gas (150 kBtu output) / DX (10 Ton) RTU which is controlled by a programmable thermostat. When the technician reviews the thermostat schedule they find the unoccupied schedule is programmed incorrectly. During the unoccupied periods the fan is programmed correctly, and runs in intermittent “auto” mode, although the heating and cooling temperature setpoints are not setback.

The technician adjusts the unoccupied schedule to include a 10°F cooling and heating temperature setback during the unoccupied periods.

\[
\Delta\text{kWh} = [\text{Baseline Energy Use (kWh/Ton)} - \text{Proposed Energy Use (kWh/Ton)}] \times \text{Cooling Capacity (Tons)}
\]

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise, \(Fo=\text{Continuous}\)

\[
= CZ+Fu*(7.082*Tc-41.199*Th+18.734*Ws-3288.55)+Tc*(0.205*Ws-34.929)
\]

\[= 5047.662+1*(7.082*0-41.199*0+18.734*55-3288.55)+0*(0.205*55-34.929)\]

\[= 2,789.482 \text{ kWh/Ton}\]

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise, \(Fo=\text{Continuous}\)

\[= CZ+Fu*(7.082*Tc-41.199*Th+18.734*Ws-3288.55)+Tc*10*(0.205*Ws-34.929)\]

\[= 5047.662+10*(7.082*10-41.199*10+18.734*55-3288.55)+10*(0.205*55-34.929)\]

\[= 2,211.722 \text{ kWh/Ton}\]

\[\Delta\text{kWh} = [2,789.482 (\text{kWh/Ton}) - 2,211.722 (\text{kWh/Ton})] \times 10 \text{Tons}\]

\[= 577.71 \text{ kWh/Ton} \times 10 \text{Tons}\]

\[= 577.71 \text{ kWh}\]
**NATURAL GAS ENERGY SAVINGS**

\[
\Delta \text{Therms} = [\text{Baseline Energy Use (Therms/kBtuh)} - \text{Proposed Energy Use(Therms/kBtuh)}] \times \text{Output Heating Capacity (kBtuh)}
\]

The following equations are used to calculate baseline and proposed natural gas energy use. The savings is the difference between the proposed and baseline calculated usage. This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.

**Natural Gas Energy Use Equations (therms / kbtu)**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>(\text{CZ} + \text{Fu} \times (0.2323 \times \text{Th} + 0.9841 \times \text{Ws} - 18.79) + \text{Th} \times (0.00271 \times \text{Ws} - 0.535) + 0.0142 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.00405 \times \text{Th} + 0.000519 \times \text{Ws} - 0.11) + \text{Th} \times (0.000689 \times \text{Ws} - 0.0118) + 0.0022 \times \text{Ws})</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>(\text{CZ} + \text{Fu} \times (0.00545 \times \text{Th} - 0.00251 \times \text{Ws} + 0.416) + \text{Th} \times (0.00123 \times \text{Ws} - 0.0204) + 0.00183 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.00231 \times \text{Th} - 0.0349) + \text{Th} \times (0.0000689 \times \text{Ws} - 0.0118) + 0.00169 \times \text{Ws})</td>
</tr>
<tr>
<td>Office – Low Rise</td>
<td>Continuous</td>
<td>(\text{CZ} + \text{Fu} \times (0.0205 \times \text{Th} + 0.364) + \text{Th} \times (0.00046 \times \text{Ws} - 0.0554) + 0.00169 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.00745 \times \text{Th} - 0.00251 \times \text{Ws} + 0.416) + \text{Th} \times (0.0000689 \times \text{Ws} - 0.0118) + 0.00183 \times \text{Ws})</td>
</tr>
<tr>
<td>Religious</td>
<td>Continuous</td>
<td>(\text{CZ} + 0.00791 \times \text{Fu} \times \text{Th} + \text{Th} \times (0.00096 \times \text{Ws} - 0.167) + 0.00184 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.00143 \times \text{Th} - 0.0309) + \text{Th} \times (0.00088 \times \text{Ws} - 0.134) + 0.00219 \times \text{Ws})</td>
</tr>
<tr>
<td>Restaurant – Fast Food</td>
<td>Continuous</td>
<td>(\text{CZ} + \text{Fu} \times (0.0431 \times \text{Th} + 0.0424 \times \text{Ws} - 7.517) + \text{Th} \times (0.00113 \times \text{Ws} - 0.213) + 0.0119 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.0125 \times \text{Th} + 0.0036 \times \text{Ws} - 0.71) + \text{Th} \times (0.000329 \times \text{Ws} - 0.0615) + 0.00738 \times \text{Ws})</td>
</tr>
<tr>
<td>Restaurant – Sit Down</td>
<td>Continuous</td>
<td>(\text{CZ} + \text{Fu} \times (0.00445 \times \text{Ws} - 0.535) + \text{Th} \times (0.000679 \times \text{Ws} - 0.1) + 0.00218 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.00144 \times \text{Th} - 0.00262 \times \text{Ws} - 0.0553) + \text{Th} \times (0.00018 \times \text{Ws} - 0.0299) + 0.00166 \times \text{Ws})</td>
</tr>
<tr>
<td>Retail – Large</td>
<td>Continuous</td>
<td>(\text{CZ} + 0.00203 \times \text{Fu} \times \text{Th} + \text{Th} \times (0.000591 \times \text{Ws} - 0.0812) + 0.00194 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Th} \times (0.000406 \times \text{Ws} - 0.0611) + 0.00228 \times \text{Ws})</td>
</tr>
<tr>
<td>Retail – Strip Mall</td>
<td>Continuous</td>
<td>(\text{CZ} + \text{Fu} \times (0.009998 \times \text{Th} - 0.00207 \times \text{Ws} - 0.206) + \text{Th} \times (0.000665 \times \text{Ws} - 0.101) + 0.00292 \times \text{Ws})</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>(\text{CZ} + \text{Fu} \times (0.00383 \times \text{Th} - 0.0656) + \text{Th} \times (0.000575 \times \text{Ws} - 0.0912) + 0.00249 \times \text{Ws})</td>
</tr>
</tbody>
</table>

Where:

- **CZ** = Climate Zone Coefficient
- **Th** = Degrees of Heating Setback °F
- **Fo** = Fan Mode During Occupied Period (Note: Commercial mechanical code requires continuous fan operation during occupied periods to meet ventilation requirements.)
- **Fu** = Fan Mode during Unoccupied Period

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A
= 0 for unoccupied fan that runs continuously (e.g. Fan Mode Set to ‘On’)
= 1 for unoccupied fan that runs intermittently (e.g. Fan Mode Set to ‘Auto’)

Ws = Weekly Hours thermostat is in Occupied mode,
= Minimum values depends on Building Type (see table below), maximum value of 168 (24/7)
ex: Weekly occupancy schedule of Mon-Sat 8AM-5PM, Sun 9AM-2PM, Ws = 59.

### Natural Gas Energy Use Climate Zone Coefficients and Minimum Weekly Hours Occupied

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Fan Mode During Occupied Period (Fo)</th>
<th>Climate Zone Coefficient (CZ)</th>
<th>Minimum Ws</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Assembly</td>
<td>Continuous</td>
<td>19.872</td>
<td>17.83</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>0.237</td>
<td>0.0989</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>Continuous</td>
<td>1.493</td>
<td>1.081</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>1.128</td>
<td>0.854</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>Continuous</td>
<td>1.718</td>
<td>1.317</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>3.447</td>
<td>3.022</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>5.914</td>
<td>5.368</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>5.247</td>
<td>4.484</td>
</tr>
<tr>
<td>Restaurant – Full</td>
<td>Continuous</td>
<td>1.227</td>
<td>0.636</td>
</tr>
<tr>
<td>Service</td>
<td>Intermittent</td>
<td>0.951</td>
<td>0.704</td>
</tr>
<tr>
<td>Retail – Department</td>
<td>Continuous</td>
<td>4.385</td>
<td>3.854</td>
</tr>
<tr>
<td>Store</td>
<td>Intermittent</td>
<td>3.061</td>
<td>2.672</td>
</tr>
<tr>
<td>Retail – Strip Mall</td>
<td>Continuous</td>
<td>3.917</td>
<td>3.394</td>
</tr>
<tr>
<td></td>
<td>Intermittent</td>
<td>2.659</td>
<td>2.292</td>
</tr>
</tbody>
</table>
EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is occupied Mon-Fri 7AM-6PM and is heated and cooled with a packaged Gas (150 kBTU output) / DX (10 Ton) RTU which is controlled by a programmable thermostat. When the technician reviews the thermostat schedule they find the unoccupied schedule is programmed incorrectly. During the unoccupied periods the fan is programmed correctly, and runs in intermittent “auto” mode, although the heating and cooling temperature setpoints are not setback.

The technician adjusts the unoccupied schedule to include a 10°F cooling and heating temperature setback during the unoccupied periods.

\[ \Delta \text{Therms} = [\text{Baseline Energy Use (Therms/kBtuh)} - \text{Proposed Energy Use (Therms/kBtuh)}] \times \text{Output Heating Capacity (kBtuh)} \]

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise, \( F_o = \text{Continuous} \)

\[ = CZ + Fu \times (0.0205 \times Th + 0.364) + Th \times (0.00046 \times Ws - 0.0554) + 0.00169 \times Ws \]

\[ = 1.718 + 1 \times (0.0205 \times 0 + 0.364) + 0 \times (0.00046 \times 55 - 0.0554) + 0.00169 \times 55 \]

\[ = 2.17495 \text{ Therms/kBtuh output} \]

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise, \( F_o = \text{Continuous} \)

\[ = CZ + Fu \times (0.0205 \times Th + 0.364) + Th \times (0.00046 \times Ws - 0.0554) + 0.00169 \times Ws \]

\[ = 1.718 + 1 \times (0.0205 \times 10 + 0.364) + 10 \times (0.00046 \times 55 - 0.0554) + 0.00169 \times 55 \]

\[ = 2.07895 \text{ Therms/kBtuh output} \]

\[ \Delta \text{Therms} = [2.17495 \text{ ( Therms/kBtuh output)} - 2.07895 \text{ ( Therms/kBtuh output)}] \times 150\text{kBtuh output} \]

\[ = 0.096 \text{ (Therms/kBtuh output)} \times 150\text{kBtuh output} \]

\[ = 14.4 \text{ Therms} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-PRGA-V01-150601

REVIEW DEADLINE: 1/1/2022
4.4.26 Variable Speed Drives for HVAC Supply and Return Fans

**DESCRIPTION**

This measure is applied to variable speed drives (VSD) which are installed on HVAC supply fans and return fans. There is a separate measure for HVAC pumps and cooling tower fans. All other VSD applications require custom analysis by the program administrator. The VSD will modulate the speed of the motor when it does not need to run at full load. Since the power of the motor is proportional to the cube of the speed for these types of applications, significant energy savings will result.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

The VSD is applied to a motor which does not have a VSD. The application must have a variable load and installation is to include the necessary controls. Savings are based on application of VSDs to a range of baseline load conditions including no control, inlet guide vanes, outlet guide vanes and throttling valves.

**DEFINITION OF BASELINE EQUIPMENT**

The time of sale baseline is a new motor installed without a VSD or other methods of control. Retrofit baseline is an existing motor operating as is. Retrofit baselines may or may not include guide vanes, throttling valves or other methods of control. This information shall be collected from the customer.

Installations of new equipment with VSDs which are required by IECC 2012 or 2015 as adopted by the State of Illinois are not eligible for incentives.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life for HVAC application is 15 years; measure life for process is 10 years.

**DEEMED MEASURE COST**

Customer provided costs will be used when available. Default measure costs are noted below for up to 20 hp motors. Custom costs must be gathered from the customer for motor sizes not listed below.

<table>
<thead>
<tr>
<th>HP</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5 HP</td>
<td>$1,330</td>
</tr>
<tr>
<td>7.5 HP</td>
<td>$1,622</td>
</tr>
<tr>
<td>10 HP</td>
<td>$1,898</td>
</tr>
<tr>
<td>15 HP</td>
<td>$2,518</td>
</tr>
<tr>
<td>20 HP</td>
<td>$3,059</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

- Loadshape C39 - VFD - Supply fans <10 HP
- Loadshape C40 - VFD - Return fans <10 HP
- Loadshape C41 - VFD - Exhaust fans <10 HP

---

463 Efficiency Vermont TRM 10/26/11 for HVAC VSD motors
464 DEER 2008
COINCIDENCE FACTOR

The demand savings factor (DSF) is already based upon coincident savings, and thus there is no additional coincidence factor for this characterization.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS\textsuperscript{466}

\[
\begin{align*}
\text{kWh}_{\text{Base}} &= \left(0.746 \times HP \times \frac{LF}{\eta_{\text{motor}}}ight) \times RHR_{\text{Base}} \times \sum_{0\%}^{100\%} (\%FF \times PLR_{\text{Base}}) \\
\text{kWh}_{\text{Retrofit}} &= \left(0.746 \times HP \times \frac{LF}{\eta_{\text{motor}}}ight) \times RHR_{\text{Base}} \times \sum_{0\%}^{100\%} (\%FF \times PLR_{\text{Retrofit}}) \\
\Delta\text{kWh}_{\text{fan}} &= \text{kWh}_{\text{Base}} - \text{kWh}_{\text{Retrofit}} \\
\Delta\text{kWh}_{\text{total}} &= \Delta\text{kWh}_{\text{fan}} \times (1 + IE_{\text{energy}})
\end{align*}
\]

Where:

- \(kWh_{\text{Base}}\) = Baseline annual energy consumption (kWh/yr)
- \(kWh_{\text{Retrofit}}\) = Retrofit annual energy consumption (kWh/yr)
- \(\Delta kWh_{\text{fan}}\) = Fan-only annual energy savings
- \(\Delta kWh_{\text{total}}\) = Total project annual energy savings
- 0.746 = Conversion factor for HP to kWh

\[
\begin{align*}
\text{HP} &= \text{Nominal horsepower of controlled motor} \\
\text{LF} &= \text{Load Factor; Motor Load at Fan Design CFM (Default = 65\%)}\textsuperscript{467} \\
\eta_{\text{motor}} &= \text{Installed nominal/nameplate motor efficiency}
\end{align*}
\]

### NEMA Premium Efficiency Motors Default Efficiencies

<table>
<thead>
<tr>
<th>Size HP</th>
<th>Open Drip Proof (ODP)</th>
<th># of Poles</th>
<th>Totally Enclosed Fan-Cooled (TEFC)</th>
<th># of Poles</th>
<th>Speed (RPM)</th>
<th>Speed (RPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1200</td>
<td>1800</td>
<td>3600</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.825</td>
<td>0.855</td>
<td>0.770</td>
<td>0.825</td>
<td>0.855</td>
<td>0.770</td>
</tr>
<tr>
<td>1.5</td>
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<td>0.865</td>
<td>0.840</td>
<td>0.875</td>
<td>0.865</td>
<td>0.840</td>
</tr>
<tr>
<td>2</td>
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<td>0.885</td>
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<td>0.855</td>
</tr>
<tr>
<td>3</td>
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<td>0.855</td>
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<td>0.865</td>
</tr>
<tr>
<td>5</td>
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<td>0.895</td>
<td>0.865</td>
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<td>0.895</td>
<td>0.885</td>
</tr>
<tr>
<td>7.5</td>
<td>0.902</td>
<td>0.910</td>
<td>0.885</td>
<td>0.910</td>
<td>0.917</td>
<td>0.895</td>
</tr>
<tr>
<td>10</td>
<td>0.917</td>
<td>0.917</td>
<td>0.895</td>
<td>0.910</td>
<td>0.917</td>
<td>0.902</td>
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<tr>
<td>15</td>
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<td>0.917</td>
<td>0.924</td>
<td>0.910</td>
</tr>
<tr>
<td>20</td>
<td>0.924</td>
<td>0.930</td>
<td>0.910</td>
<td>0.917</td>
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<td>0.910</td>
</tr>
<tr>
<td>25</td>
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<td>0.917</td>
<td>0.930</td>
<td>0.936</td>
<td>0.917</td>
</tr>
<tr>
<td>30</td>
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<td>0.917</td>
<td>0.930</td>
<td>0.936</td>
<td>0.917</td>
</tr>
<tr>
<td>40</td>
<td>0.941</td>
<td>0.941</td>
<td>0.924</td>
<td>0.941</td>
<td>0.941</td>
<td>0.924</td>
</tr>
<tr>
<td>50</td>
<td>0.941</td>
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<td>0.930</td>
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<td>0.945</td>
<td>0.930</td>
</tr>
<tr>
<td>60</td>
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<td>0.950</td>
<td>0.936</td>
<td>0.945</td>
<td>0.950</td>
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<tr>
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<td>0.954</td>
<td>0.936</td>
</tr>
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<td>0.954</td>
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</tr>
<tr>
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<td>0.950</td>
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<td>0.950</td>
<td>0.954</td>
<td>0.950</td>
</tr>
<tr>
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<td>0.941</td>
<td>0.950</td>
<td>0.954</td>
<td>0.950</td>
</tr>
<tr>
<td>200</td>
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<td>0.958</td>
<td>0.950</td>
<td>0.958</td>
<td>0.962</td>
<td>0.954</td>
</tr>
<tr>
<td>250</td>
<td>0.954</td>
<td>0.958</td>
<td>0.950</td>
<td>0.958</td>
<td>0.962</td>
<td>0.958</td>
</tr>
<tr>
<td>300</td>
<td>0.954</td>
<td>0.958</td>
<td>0.954</td>
<td>0.958</td>
<td>0.962</td>
<td>0.958</td>
</tr>
<tr>
<td>350</td>
<td>0.954</td>
<td>0.958</td>
<td>0.954</td>
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<td>0.962</td>
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<td>0.958</td>
</tr>
<tr>
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<td>0.958</td>
<td>0.958</td>
<td>0.962</td>
<td>0.958</td>
</tr>
</tbody>
</table>

\[
RHRS_{\text{Base}} = \text{Annual operating hours for fan motor based on building type}
\]

Default hours are provided for HVAC applications which vary by HVAC application and building type. When available, actual hours should be used.

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Total Fan Run Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>7235</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>8760</td>
</tr>
<tr>
<td>College</td>
<td>6103</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>7004</td>
</tr>
<tr>
<td>Elementary School</td>
<td>7522</td>
</tr>
</tbody>
</table>


469 Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.
### Building Type

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Total Fan Run Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garage</td>
<td>7357</td>
</tr>
<tr>
<td>Grocery</td>
<td>7403</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>6345</td>
</tr>
<tr>
<td>High School</td>
<td>7879</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>8760</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>8706</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>8760</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>8760</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>8760</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>8760</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>7505</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>6064</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td>5697</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td>5682</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td>6163</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>6288</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>6125</td>
</tr>
<tr>
<td>Religious Building</td>
<td>7380</td>
</tr>
<tr>
<td>Restaurant</td>
<td>7809</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>6890</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>6846</td>
</tr>
<tr>
<td>Warehouse</td>
<td>6786</td>
</tr>
<tr>
<td>Unknown</td>
<td>7100</td>
</tr>
</tbody>
</table>

\[
\%FF = \text{Percentage of run-time spent within a given flow fraction range}
\]

Default Fan Duty Cycle Based on 2012 ASHRAE Handbook; HVAC Systems and Equipment, page 45.11, Figure 12.

<table>
<thead>
<tr>
<th>Flow Fraction (% of design cfm)</th>
<th>Percent of Time at Flow Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% to 10%</td>
<td>0.0%</td>
</tr>
<tr>
<td>10% to 20%</td>
<td>1.0%</td>
</tr>
<tr>
<td>20% to 30%</td>
<td>5.5%</td>
</tr>
<tr>
<td>30% to 40%</td>
<td>15.5%</td>
</tr>
<tr>
<td>40% to 50%</td>
<td>22.0%</td>
</tr>
<tr>
<td>50% to 60%</td>
<td>25.0%</td>
</tr>
<tr>
<td>60% to 70%</td>
<td>19.0%</td>
</tr>
<tr>
<td>70% to 80%</td>
<td>8.5%</td>
</tr>
<tr>
<td>80% to 90%</td>
<td>3.0%</td>
</tr>
<tr>
<td>90% to 100%</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

\[
PLR_{Base} = \text{Part load ratio for a given flow fraction range based on the baseline flow control type}
\]

\[
PLR_{Retrofit} = \text{Part load ratio for a given flow fraction range based on the retrofit flow control type}
\]
<table>
<thead>
<tr>
<th>Control Type</th>
<th>Flow Fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>No Control or Bypass Damper</td>
<td>1.00</td>
</tr>
<tr>
<td>Discharge Dampers</td>
<td>0.46</td>
</tr>
<tr>
<td>Outlet Damper, BI &amp; Airfoil Fans</td>
<td>0.53</td>
</tr>
<tr>
<td>Inlet Damper Box</td>
<td>0.56</td>
</tr>
<tr>
<td>Inlet Guide Vane, BI &amp; Airfoil Fans</td>
<td>0.53</td>
</tr>
<tr>
<td>Inlet Vane Dampers</td>
<td>0.38</td>
</tr>
<tr>
<td>Outlet Damper, FC Fans</td>
<td>0.22</td>
</tr>
<tr>
<td>Eddy Current Drives</td>
<td>0.17</td>
</tr>
<tr>
<td>Inlet Guide Vane, FC Fans</td>
<td>0.21</td>
</tr>
<tr>
<td>VFD with duct static pressure controls</td>
<td>0.09</td>
</tr>
<tr>
<td>VFD with low/no duct static pressure</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Provided below is the resultant values based upon the defaults provided above:

<table>
<thead>
<tr>
<th>Control Type</th>
<th>(\frac{100%}{\sum_{FF}FF \times PLR_{Base}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Control or Bypass Damper</td>
<td>1.00</td>
</tr>
<tr>
<td>Discharge Dampers</td>
<td>0.80</td>
</tr>
<tr>
<td>Outlet Damper, BI &amp; Airfoil Fans</td>
<td>0.78</td>
</tr>
<tr>
<td>Inlet Damper Box</td>
<td>0.69</td>
</tr>
<tr>
<td>Inlet Guide Vane, BI &amp; Airfoil Fans</td>
<td>0.63</td>
</tr>
<tr>
<td>Inlet Vane Dampers</td>
<td>0.53</td>
</tr>
<tr>
<td>Outlet Damper, FC Fans</td>
<td>0.53</td>
</tr>
<tr>
<td>Eddy Current Drives</td>
<td>0.49</td>
</tr>
<tr>
<td>Inlet Guide Vane, FC Fans</td>
<td>0.39</td>
</tr>
<tr>
<td>VFD with duct static pressure controls</td>
<td>0.30</td>
</tr>
<tr>
<td>VFD with low/no duct static pressure</td>
<td>0.27</td>
</tr>
</tbody>
</table>

\[ IE_{energy} = \text{HVAC interactive effects factor for energy (default = 15.7\%)} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\text{kW}_{Base} = \left( 0.746 \times HP \times \frac{LF}{\eta_{motor}} \right) \times PLR_{Base,FFpeak} \\
\text{kW}_{Retrofit} = \left( 0.746 \times HP \times \frac{LF}{\eta_{motor}} \right) \times PLR_{Retrofit,FFpeak} \\
\Delta kW_{fan} = kW_{Base} - kW_{Retrofit} \\
\Delta kW_{total} = \Delta kW_{fan} \times (1 + IE_{demand})
\]

Where:

\[ kW_{Base} = \text{Baseline summer coincident peak demand (kW)} \]
There are no expected fossil fuel impacts for this measure.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-VSDF-V02-160601**

**REVIEW DEADLINE: 1/1/2021**
4.4.27 Energy Recovery Ventilator

DESCRIPTION

This measure includes the addition of energy recovery equipment on existing or new unitary equipment, where energy recovery is not required by the IECC 2012/2015. This measure analyzes the heating savings potential from recovering energy from exhaust or relief building air. This measure assumes during unoccupied hours of the building no exhaust or relief air is available for energy recovery.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Efficient equipment is unitary equipment that incorporates energy recovery not required by the IECC 2012/2015.

DEFINITION OF BASELINE EQUIPMENT

The baseline is unitary equipment not required by IECC 2012/2015 to incorporate energy recovery.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life for the domestic energy recovery equipment is 15 years.470

DEEMED MEASURE COST

The incremental cost for this measure assumes cost of cabinet and controls incorporated into packaged and built up air handler units. Additionally it assumes 1 to 1 ratio of fresh and exhausted air.

<table>
<thead>
<tr>
<th>Energy Recovery Equipment Type</th>
<th>Incremental Cost $/CFM471</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Plate</td>
<td>$6</td>
</tr>
<tr>
<td>Rotary Wheel</td>
<td>$6</td>
</tr>
<tr>
<td>Heat Pipe</td>
<td>$6</td>
</tr>
</tbody>
</table>

DEEMED O&M COST ADJUSTMENTS

There are no expected O&M savings associated with this measure.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

---


CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

SUMMER COINCIDENT PEAK DEMAND SAVINGS

There are no anticipated electrical savings from this measure as it is assumed that the additional fan energy due to the increased static pressure drop offsets cooling energy savings. Where this is not expected to be the case, a custom calculation should be used to determine the savings.

NATURAL GAS SAVINGS

Gas savings algorithm is derived from the following:

$$\Delta \text{Therms} = \frac{(\text{Design Heating Load} \times \text{TE}_{\text{ERV}} \times \text{EFLH} \times \text{OccHours}/24)}{(100,000 \times \mu_{\text{Heat}})}$$

Where:

Design Heating Load = \((1.08 \times \text{CFM} \times \Delta T)\)

1.08 = A constant for sensible heat equations (BTU/h/CFM°F)

CFM = Cubic Feet per Minute of Energy Recovery Ventilator

$$\Delta T = T_{RA} - T_{DD}$$

$$T_{RA}$$ = Temperature of the Return Air = 70°F or custom

$$T_{DD}$$ = Temperature on design day of outside air\textsuperscript{472}

= (see Table below) or custom

<table>
<thead>
<tr>
<th>Zone</th>
<th>Weather Station</th>
<th>T_DD, Temperature, °F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Greater Rockford</td>
<td>-5.8</td>
</tr>
<tr>
<td>2</td>
<td>Chicago/O’Hare ARPT.</td>
<td>-1.5</td>
</tr>
<tr>
<td>3</td>
<td>Springfield/Capital</td>
<td>0.4</td>
</tr>
<tr>
<td>4</td>
<td>Scott AFB MidAmerica</td>
<td>9.0</td>
</tr>
<tr>
<td>5</td>
<td>Cape Girardeau Regional</td>
<td>9.7</td>
</tr>
<tr>
<td>Average</td>
<td>-</td>
<td>2.4</td>
</tr>
</tbody>
</table>

$$\text{TE}_{\text{ERV}}$$ = Thermal Effectiveness of Energy Recovery Equipment\textsuperscript{473}

= (see Table below) or custom

<table>
<thead>
<tr>
<th>Heat Recovery Equipment Type</th>
<th>TE_{ERV} (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Plate</td>
<td>0.65</td>
</tr>
<tr>
<td>Rotary Equipment</td>
<td>0.68</td>
</tr>
<tr>
<td>Heat Pipe</td>
<td>0.55</td>
</tr>
</tbody>
</table>

\textsuperscript{472}Weather Station Data, 99.6% Heating DB - 2013 Fundamentals, ASHRAE Handbook

\textsuperscript{473}Energy Recovery Fact Sheet - Center Point Energy, MN
EFLH  = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use
OccHours  = Average Hours per day facility is occupied

= custom or use Modeling Inputs in eQuest models:

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Weekday</th>
<th>Saturday</th>
<th>Sunday</th>
<th>Holiday</th>
<th>Annual Operating Hours</th>
<th>OccHours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly/Convention Center</td>
<td>10am-9pm</td>
<td>10am-9pm</td>
<td>10am-9pm</td>
<td>closed</td>
<td>3905</td>
<td>10.7</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>24/7</td>
<td>24/7</td>
<td>24/7</td>
<td>24/7</td>
<td>8760</td>
<td>24.0</td>
</tr>
<tr>
<td>College</td>
<td>8am-9pm</td>
<td>closed</td>
<td>closed</td>
<td>closed</td>
<td>3263</td>
<td>8.9</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>7am-10pm</td>
<td>9am-9pm</td>
<td>10am-5pm</td>
<td>10am-5pm</td>
<td>4823</td>
<td>13.2</td>
</tr>
<tr>
<td>Elementary School</td>
<td>8am-4pm</td>
<td>closed</td>
<td>closed</td>
<td>closed</td>
<td>1606</td>
<td>4.4</td>
</tr>
<tr>
<td>Garage</td>
<td>7am-5pm</td>
<td>8am-12pm</td>
<td>closed</td>
<td>closed</td>
<td>3342</td>
<td>9.1</td>
</tr>
<tr>
<td>Grocery</td>
<td>7am-9pm</td>
<td>7am-9pm</td>
<td>9am-8pm</td>
<td>closed</td>
<td>4814</td>
<td>13.2</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>7am-7pm</td>
<td>9am-5pm</td>
<td>closed</td>
<td>closed</td>
<td>3428</td>
<td>9.4</td>
</tr>
<tr>
<td>High School</td>
<td>8am-4pm</td>
<td>closed</td>
<td>closed</td>
<td>closed</td>
<td>1606</td>
<td>4.4</td>
</tr>
<tr>
<td>Hospital</td>
<td>24/7</td>
<td>24/7</td>
<td>24/7</td>
<td>24/7</td>
<td>8760</td>
<td>24.0</td>
</tr>
<tr>
<td>Motel</td>
<td>24/7</td>
<td>24/7</td>
<td>24/7</td>
<td>24/7</td>
<td>8760</td>
<td>24.0</td>
</tr>
<tr>
<td>Manufacturing Facility (Light Industry)</td>
<td>Mfg: 6am-10pm, Office: 8am-5pm</td>
<td>Mfg: 6am-10pm, Office: closed</td>
<td>closed</td>
<td>closed</td>
<td>4848</td>
<td>13.3</td>
</tr>
<tr>
<td>Multi-Family Mid-Rise</td>
<td>24/7; Reduced occupancy 7am - 5pm</td>
<td>24/7; Reduced occupancy 9am - 3pm</td>
<td>24/7; Reduced occupancy 9am - 3pm</td>
<td>24/7; Reduced occupancy 9am - 3pm</td>
<td>7038</td>
<td>19.3</td>
</tr>
<tr>
<td>Multi-Family High-Rise</td>
<td>24/7; Reduced occupancy 7am - 5pm</td>
<td>24/7; Reduced occupancy 9am - 3pm</td>
<td>24/7; Reduced occupancy 9am - 3pm</td>
<td>24/7; Reduced occupancy 9am - 3pm</td>
<td>7038</td>
<td>19.3</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>10am- Midnight</td>
<td>10am- Midnight</td>
<td>10am- Midnight</td>
<td>10am- Midnight</td>
<td>5110</td>
<td>14.0</td>
</tr>
<tr>
<td>Office - Low-rise</td>
<td>8am-5pm</td>
<td>closed</td>
<td>closed</td>
<td>closed</td>
<td>2259</td>
<td>6.2</td>
</tr>
<tr>
<td>Office - Mid-rise</td>
<td>8am-5pm</td>
<td>20% 8am-noon</td>
<td>closed</td>
<td>closed</td>
<td>2301</td>
<td>6.3</td>
</tr>
<tr>
<td>Office - High-rise</td>
<td>8am-5pm</td>
<td>20% 8am-noon</td>
<td>closed</td>
<td>closed</td>
<td>2301</td>
<td>6.3</td>
</tr>
<tr>
<td>Religious Building</td>
<td>Office: 8am-5pm, other: closed</td>
<td>closed</td>
<td>8am-1pm</td>
<td>closed</td>
<td>260</td>
<td>0.7</td>
</tr>
<tr>
<td>Restaurant</td>
<td>7am-8pm</td>
<td>7am-8pm</td>
<td>7am-8pm</td>
<td>closed</td>
<td>4615</td>
<td>12.6</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>9am-9pm</td>
<td>9am-9pm</td>
<td>10am-5pm</td>
<td>10am-5pm</td>
<td>4070</td>
<td>11.1</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>9am-9pm</td>
<td>9am-9pm</td>
<td>10am-5pm</td>
<td>10am-5pm</td>
<td>4070</td>
<td>11.1</td>
</tr>
<tr>
<td>Warehouse (Conditioned Storage)</td>
<td>7am-7pm</td>
<td>7am-7pm (reduced occupancy)</td>
<td>closed</td>
<td>closed</td>
<td>3324</td>
<td>9.1</td>
</tr>
</tbody>
</table>

µHeat  = Efficiency of heating system

= Actual
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-ERVE-V02-160601

REVIEW DEADLINE: 1/1/2022
4.4.28 Stack Economizer for Boilers Serving HVAC Loads

**MEASURE DESCRIPTION**

Stack economizers are designed to recover heat from hot boiler flue gasses. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of HVAC boilers with stack economizers. HVAC boilers are defined as those used for space heating applications. There is another, similar measure for boilers that serve process loads.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify the economizer must be installed on a boiler exhaust stack. Heat captured by the economizer is to be used to pre-heat boiler feed water.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline boiler does not have an economizer installed.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the boiler stack economizer is 15 years.\(^{474}\)

**DEEMED MEASURE COST**

The incremental and full measure cost for this measure is custom.

**DEEMED O&M COST ADJUSTMENTS**

The O&M cost for this measure is custom.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

---

**Algorithm**

<table>
<thead>
<tr>
<th>Energy Savings</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELECTRIC ENERGY SAVINGS</td>
<td>N/A</td>
</tr>
<tr>
<td>SUMMER COINCIDENT PEAK DEMAND SAVINGS</td>
<td>N/A</td>
</tr>
<tr>
<td>NATURAL GAS SAVINGS</td>
<td>[ \Delta \text{therms} = \text{SF} \times \text{MBH}_{\text{In}} \times \text{EFLH} / 100 ]</td>
</tr>
</tbody>
</table>

Where:

\[
SF = \frac{(T_{\text{existing}} - T_{\text{eff}})}{40^\circ F} \times \text{TRE}
\]

= see default Savings Factor table below

Where:

\[
T_{\text{existing}} = \text{Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack}
\]

= 425°F (water, 81.9% eff) or custom

= 480°F (steam, 80.7% eff) or custom

\[
T_{\text{eff}} = \text{Efficient Full Fire Boiler Flue Gas Temperature as it exits the Stack}
\]

= 338°F (conventional economizer – Water Boiler) or custom

= 365°F (conventional economizer – Steam Boiler) or custom

= 280°F (condensing economizer – Water Boiler) or custom

= 308°F (condensing economizer – Steam Boiler) or custom

\[
\text{TRE} = \% \text{ efficiency increase for 40°F of stack temperature reduction}
\]

= 1% or custom

Based on defaults provided above:

<table>
<thead>
<tr>
<th>Boiler Type</th>
<th>Conventional Economizer SF</th>
<th>Condensing Economizer SF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Water Boiler</td>
<td>2.19% average SF or custom</td>
<td>3.63% average SF or custom</td>
</tr>
<tr>
<td>Steam Boiler</td>
<td>2.88% average SF or custom</td>
<td>4.31% average SF or custom</td>
</tr>
</tbody>
</table>

MBH_In = Rated boiler input capacity, in MBH

= Actual

---

475 Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.
476 The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \(\frac{1}{2}\) way between the existing and efficient temperature minimum, \((425^\circ F + 250^\circ F) / 2 = 338^\circ F\).
477 The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \(\frac{1}{2}\) way between the existing and efficient temperature minimum, \((480^\circ F + 250^\circ F) / 2 = 365^\circ F\).
478 The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \(\frac{1}{2}\) way between the existing and efficient temperature minimum, \((425^\circ F + 135^\circ F) / 2 = 280^\circ F\).
479 The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \(\frac{1}{2}\) way between the existing and efficient temperature minimum, \((480^\circ F + 135^\circ F) / 2 = 308^\circ F\).
480 United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998. The Wise Rules indicate savings range of 1-2% per 40°F reduction, so utilizing 1% is a conservative approach.
481 These average values should be utilized in absence of actual temperature data. An economizer with a zero temperature change between the existing and the efficient temperatures would not be installed, so these average values are conservative.
EFLH = Equivalent Full Load Hours for heating are provided in Section 4.4 HVAC End Use

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-HVC-BECO-V01-150601**

**REVIEW DEADLINE: 1/1/2021**
4.4.29 Stack Economizer for Boilers Serving Process Loads

**Measure Description**

Stack economizers are designed to recover heat from hot boiler flue gasses. Recovered heat is used to preheat boiler feed water. This measure describes the retrofit of process boilers with stack economizers. Process boilers are defined as those used for industrial, manufacturing, or other non-HVAC applications. There is another, similar measure for boilers that serve HVAC loads.

This measure was developed to be applicable to the following program types: NC, TOS, RF.

If applied to other program types, the measure savings should be verified.

**Definition of Efficient Equipment**

To qualify the economizer must be installed on a boiler exhaust stack. Heat captured by the economizer is to be used to pre-heat boiler feed water.

**Definition of Baseline Equipment**

The baseline boiler does not have an economizer installed.

**Deemed Lifetime of Efficient Equipment**

The measure life for the boiler stack economizer is 15 years.\(^{482}\)

**Deemed Measure Cost**

The incremental and full measure cost for this measure is custom.

**Deemed O&M Cost Adjustments**

The O&M cost for this measure is custom.

**Loadshape**

N/A

**Coincidence Factor**

N/A

---

**Algorithm**

**Calculation of Energy Savings**

**Electric Energy Savings**

N/A

**Summer Coincident Peak Demand Savings**

N/A

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**Natural Gas Savings**

\[ \Delta \text{therms} = SF \times \text{MBH}_\text{In} \times 8766 \times UF / 100 \]

Where:

- **SF** = \( (T\text{\_existing} - T\text{\_eff})/40^\circ \text{F} \times \text{TRE} \)
  - see default Savings Factor table below

- **T\text{\_existing}** = Existing Full Fire Boiler Flue Gas Temperature as it exits the Stack
  - 425°F\(^{483}\) (water, 81.9% eff per IL TRM) or custom
  - 480°F\(^{483}\) (steam, 80.7% eff per IL TRM) or custom

- **T\text{\_eff}** = Efficient Full Fire Boiler Flue Gas Temperature as it exits the Stack
  - 338°F (conventional economizer – Water Boiler)\(^{484}\) or custom
  - 365°F (conventional economizer – Steam Boiler)\(^{485}\) or custom
  - 280°F (condensing economizer – Water Boiler)\(^{486}\) or custom
  - 308°F (condensing economizer – Water Boiler)\(^{487}\) or custom

- **TRE** = % efficiency increase for 40°F of stack temperature reduction
  - 1%\(^{488}\) or custom

Based on defaults provided above:

<table>
<thead>
<tr>
<th>Boiler Type</th>
<th>SF(^{489})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional Economizer</td>
</tr>
<tr>
<td>Hot Water Boiler</td>
<td>2.19% average SF or custom</td>
</tr>
<tr>
<td>Steam Boiler</td>
<td>2.88% average SF or custom</td>
</tr>
</tbody>
</table>

\[ \text{MBH}_\text{In} = \text{Rated boiler input capacity, in MBH} \]

\(^{483}\) Cleaver Brooks. March 2012, Boiler Efficiency Guide, Pg. 7, Figure 1.

\(^{484}\) The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \( \frac{1}{2} \) way between the existing and efficient temperature minimum, \( (425°F + 250°F) / 2 = 338°F \).

\(^{485}\) The minimum stack temperature for a non-condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \( \frac{1}{2} \) way between the existing and efficient temperature minimum, \( (480°F + 250°F) / 2 = 365°F \).

\(^{486}\) The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \( \frac{1}{2} \) way between the existing and efficient temperature minimum, \( (425°F + 135°F) / 2 = 280°F \).

\(^{487}\) The minimum stack temperature for a condensing economizer is 250°F from Department of Energy (DOE). January 2012, Steam Tip Sheet #26A, Consider Installing a Condensing Economizer. Advanced Manufacturing Office. Washington, DC: U.S. Department of Energy. The average temperature drop is assumed to be \( \frac{1}{2} \) way between the existing and efficient temperature minimum, \( (480°F + 135°F) / 2 = 308°F \).

\(^{488}\) United States EPA, Climate Wise: Wise Rules for Industrial Efficiency, July 1998. The Wise Rules indicate savings range of 1-2% per 40°F reduction, so utilizing 1% is a conservative approach.

\(^{489}\) These average values should be utilized in absence of actual temperature data. An economizer with a zero temperature change between the existing and the efficient temperatures would not be installed, so these average values are conservative.
= Actual
8766 = Hours a year
UF = Utilization Factor
41.9% or custom

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-PECO-V01-150601

REVIEW DEADLINE: 1/1/2022

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490 Work Paper – Tune up for Boilers serving Space Heating and Process Load by Resource Solutions Group, January 2012
4.4.30 Notched V Belts for HVAC Systems

MEASURE DESCRIPTION

This measure is for replacement of smooth v-belts in non-residential package and split HVAC systems with notched v-belts or for installing new equipment with synchronous belts instead of smooth v-belts. Typically there is a v-belt between the motor and the supply air fan and/or return air fan in larger package and split HVAC systems (RTU).

In general there are two styles of grooved v-belts, notched and synchronous. The DOE defines each as follows;

Notched V-Belts - A notched belt has grooves or notches that run perpendicular to the belt’s length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts.

Synchronous Belts - Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.

Smooth v-belts are usually referred to in five basic groups:

- “L” belts are low end belts that are for small, fractional horsepower motors and these are not used in RTUs.
- “A” and “B” belts are the two types typically used in RTUs. The “A” belt is a ½ inch width by 5/16 inch thickness and the “B” belt is larger, 21/32 inch wide and 12/32 inch thick so it can carry more power. V-belts come in a wide variety of lengths where 20 to 100 inches is typical.
- “C” and “D” belts are primarily for industrial applications with high power transmission requirements.
- V-belts are provided by various vendors. The notched version of these belts typically have an “X” added to the designation. For this HVAC fans notched v-belt Replacement measure, only the “A” and “B” v-belts are considered. A typical “A” v-belt is replaced by a notched “AX” v-belt and a “B” is replaced by a “BX.” In general, smooth v-belts have an efficiency of 90% to 98% while notched v-belts have an efficiency of 95% to 98%. Because notched v-belts are more flexible they work with smaller diameter pulleys and they have less resistance to bending. Lower bending resistance increases the power transmission efficiency, lowers the waste heat, and allows the belt to last longer than a smooth belt.

Three research papers show that the notched v-belt efficiency is 2% to 5% better than a typical smooth v-belt. A fourth paper by USDOE’s Energy Efficiency and Renewable Energy group reviewed most of the earlier literature and recommended using a conservative 2% efficiency improvement for energy savings for calculations.

For this measure it is assumed that upgrading a standard smooth v-belt with a new notched v-belt will result in a fan energy reduction of 2%.

DEFINITION OF EFFICIENT EQUIPMENT

For the Notched V-Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have notched v-belts installed on the supply and/or return air fans. This can be done as a retrofit, TOS, or NC project.

---

492 “Synchronous Belt Drives Offer Low Cost Energy Savings,” Baldor., February 2009. (attached in Reference Documents)
For the Synchronous Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have synchronous belts installed on the supply and/or return air fans. This can be done as a TOS or NC project. Retrofit projects can also claim savings, but costs should be verified independently (typically the cost of installing synchronous belts as a retrofit is not economically viable).

**DEFINITION OF BASELINE EQUIPMENT**

The Baseline Equipment is HVAC RTUs that have smooth v-belts installed on the supply and/or return air fans (i.e. RTU does not already have a notched v-belt installed).

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

A v-belt has a life based on fan run hours which varies by building type based primarily on occupancy schedule because the fans are required by code to operate continuously during occupied hours. The supply and return fans will also run a few hours during unoccupied hours for heating and cooling as needed. For the notched v-belt EUL calculation, the default hours\(^ {495} \) in the following table are used for a variety of building types and HVAC applications.

\[
EUL = \frac{\text{Belt Life}}{\text{Occupancy Hours per year}}
\]

Where:

- **Belt Life** = 24,000 hours\(^ {496} \)
- **Occupancy Hours per year** = values from Table below

The notched v-belt measure EUL is summarized by building type in the following table.

**Notched v-belt Effective Useful Life (EUL)**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Total Fan Run Hours</th>
<th>EUL (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>7235</td>
<td>3.3</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>College</td>
<td>6103</td>
<td>3.9</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>7004</td>
<td>3.4</td>
</tr>
<tr>
<td>Elementary School</td>
<td>7522</td>
<td>3.2</td>
</tr>
<tr>
<td>Garage</td>
<td>7357</td>
<td>3.3</td>
</tr>
<tr>
<td>Grocery</td>
<td>7403</td>
<td>3.2</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>6345</td>
<td>3.8</td>
</tr>
<tr>
<td>High School</td>
<td>7879</td>
<td>3.0</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>8706</td>
<td>2.8</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>8760</td>
<td>2.7</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>7505</td>
<td>3.2</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>6064</td>
<td>4.0</td>
</tr>
</tbody>
</table>

\(^ {495} \) ComEd Trm June 1, 2010 page 139. The Office hours is based upon occupancy from the eQuest model developed for EFLH, since it was agreed the ComEd value was too low.

The lifetime of a synchronous belt system is the same as the lifetime of the equipment it is installed on because it is a permanent upgrade, involving the installation of toothed pulleys. Typical HVAC RTU lifetime is 15 years, which applies to synchronous belts as well. This is not to suggest that the actual belt component has an equivalent lifetime because they do require replacement. However, their O&M cost savings (derived from not having to tension, etc.) are assumed to offset the replacement cost of the belt, resulting in a net cost of zero. As a result, neither a separate lifetime nor O&M savings are quantified for synchronous belts and lifetime can therefore be considered as the lifetime of the equipment they’re installed on because it would not be possible to install a traditional or notched belt on the synchronous pulleys.

### DEEMED MEASURE COST

A review of the Grainger online\(^\text{497}\) pricing for “A,” “B,” “AX,” and “BX” v-belts showed the incremental cost to upgrade to notched v-belts would result in a 28% price increase. The notched v-belt incremental cost is summarized in the table below:

#### Notched V-belt Incremental Cost Summary

<table>
<thead>
<tr>
<th>Smooth V-Belt Industry Number</th>
<th>Outside Length (Inches)</th>
<th>Dayton Smooth V-Belt*</th>
<th>Notched V-belt Industry Number</th>
<th>Dayton Notched V-belt*</th>
<th>Price Increase</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>A30 (Item # 1A095)</td>
<td>32</td>
<td>$12.70</td>
<td>AX29 (Item # 3GWU4)</td>
<td>$17.65</td>
<td>$4.95</td>
<td>28%</td>
</tr>
<tr>
<td>B29 (Item # 6L208)</td>
<td>32</td>
<td>$16.75</td>
<td>BX29 (Item # 5TXL4)</td>
<td>$23.23</td>
<td>$6.48</td>
<td>28%</td>
</tr>
</tbody>
</table>

* Pricing based on Dayton Belts as found on Grainger Website 10/30/14

Note that the incremental cost for notched V-Belts assumes that the notched belt is purchased and installed instead of a smooth v-belt. There is no difference in the cost of installation, only the material.

#### Synchronous Belt Incremental Cost Summary

<table>
<thead>
<tr>
<th>Smooth V-Belt Industry Number</th>
<th>Smooth belt system Price*</th>
<th>Synchronous Belt Industry Number</th>
<th>Synchronous System Price*</th>
<th>Price Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belt A30 (Item # 1A095)</td>
<td>$12.70</td>
<td>Belt 1DHL5 (Item # 3221050)</td>
<td>$20.51</td>
<td>$7.81</td>
</tr>
<tr>
<td>Gearbelt pulley BK47 (Item #SUHDS)</td>
<td>$45.90</td>
<td>Gearbelt sprocket</td>
<td>$113.00</td>
<td>$67.10</td>
</tr>
</tbody>
</table>

\(^\text{497}\) Grainger catalog on-line web-site for Dayton v-belt pricing

[http://www.grainger.com/Grainger/ecatalog/N-1z0r596/Ntt-v-belts](http://www.grainger.com/Grainger/ecatalog/N-1z0r596/Ntt-v-belts)
<table>
<thead>
<tr>
<th>Smooth V-Belt Industry Number</th>
<th>Smooth belt system Price*</th>
<th>Synchronous Belt Industry Number</th>
<th>Synchronous System Price*</th>
<th>Price Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GTR-36G-8M-12 (Item # 2UWH6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Costs based on Grainger pricing.

Incremental cost for a NC or TOS project is $142. This is the price of synchronous equipment (belt, two sprockets) subtract v-belt equipment (belt, two pulleys). Labor cost is assumed to be equal in the baseline and efficient cases.

Incremental cost for a RF project is $383.81. This is the price of synchronous equipment and labor to install it (not including a trip charge) subtract the cost of the v-belt (but not the pulleys).

**DEEMED O&M COST ADJUSTMENTS**

N/A

**LOADSHAPE**

Loadshape C05 - Commercial Electric Heating and Cooling

**COINCIDENCE FACTOR**

N/A

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = \text{kW}_{\text{connected}} \times \text{Hours} \times \text{ESF} \]

Where:

\[ \text{kW}_{\text{connected}} = \text{kW of equipment is calculated using motor efficiency.} \]

\[ = (\text{HP} \times 0.746 \text{ kW/HP} \times \text{Load Factor})/\text{Motor Efficiency} \]

Load Factor =Motors are assumed to have a load factor of 80% for calculating KW if actual values cannot be determined. Custom load factor may be applied if known.

Motor Efficiency =Actual motor efficiency shall be used to calculate KW. If not known a value from the motor efficiency reference tables below should be used. Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor.

---

498 Assumed to be $150 based on mechanical contractor estimate.
499 Note that kWConnected may be determined using various methodologies. The examples provided use rated HP and assumed load factor. Other methodologies include rated voltage and full load current with assumed load factor, or actual measured voltage and current.
500 Com Ed TRM June 1, 2010
### Baseline Motor Efficiencies (EPACT)

<table>
<thead>
<tr>
<th>Size HP</th>
<th>Open Drip Proof (ODP)</th>
<th>Totally Enclosed Fan-Cooled (TEFC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of Poles 6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Speed (RPM) 1200</td>
<td>1800</td>
</tr>
<tr>
<td>1/8</td>
<td>-</td>
<td>44.00%</td>
</tr>
<tr>
<td>1/6</td>
<td>57.50%</td>
<td>62.00%</td>
</tr>
<tr>
<td>1/4</td>
<td>68.00%</td>
<td>68.00%</td>
</tr>
<tr>
<td>1/3</td>
<td>70.00%</td>
<td>70.00%</td>
</tr>
<tr>
<td>1/2</td>
<td>78.50%</td>
<td>80.00%</td>
</tr>
<tr>
<td>3/4</td>
<td>77.00%</td>
<td>78.50%</td>
</tr>
<tr>
<td>1</td>
<td>80.00%</td>
<td>82.50%</td>
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<tr>
<td>1.5</td>
<td>84.00%</td>
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<td>2</td>
<td>85.50%</td>
<td>84.00%</td>
</tr>
<tr>
<td>3</td>
<td>86.50%</td>
<td>86.50%</td>
</tr>
<tr>
<td>5</td>
<td>87.50%</td>
<td>87.50%</td>
</tr>
<tr>
<td>7.5</td>
<td>88.50%</td>
<td>88.50%</td>
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<tr>
<td>10</td>
<td>90.20%</td>
<td>89.50%</td>
</tr>
<tr>
<td>15</td>
<td>90.20%</td>
<td>91.00%</td>
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<tr>
<td>20</td>
<td>91.00%</td>
<td>91.00%</td>
</tr>
<tr>
<td>25</td>
<td>91.70%</td>
<td>91.70%</td>
</tr>
</tbody>
</table>

### Efficient Motor Efficiencies (NEMA Premium)

<table>
<thead>
<tr>
<th>Size HP</th>
<th>Open Drip Proof (ODP)</th>
<th>Totally Enclosed Fan-Cooled (TEFC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of Poles 2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Speed (RPM) 1200</td>
<td>1800 (Default)</td>
</tr>
<tr>
<td>0.125 *</td>
<td>-</td>
<td>44.00%</td>
</tr>
<tr>
<td>1/6</td>
<td>57.50%</td>
<td>62.00%</td>
</tr>
<tr>
<td>1/4</td>
<td>68.00%</td>
<td>68.00%</td>
</tr>
<tr>
<td>1/3</td>
<td>70.00%</td>
<td>70.00%</td>
</tr>
<tr>
<td>1/2</td>
<td>78.50%</td>
<td>80.00%</td>
</tr>
<tr>
<td>3/4</td>
<td>77.00%</td>
<td>78.50%</td>
</tr>
<tr>
<td>1</td>
<td>82.50%</td>
<td>85.50%</td>
</tr>
<tr>
<td>1.5</td>
<td>86.50%</td>
<td>86.50%</td>
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<tr>
<td>2</td>
<td>87.50%</td>
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<td>3</td>
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<td>5</td>
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<td>89.50%</td>
</tr>
<tr>
<td>7.5</td>
<td>90.20%</td>
<td>91.00%</td>
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<tr>
<td>10</td>
<td>91.70%</td>
<td>91.70%</td>
</tr>
<tr>
<td>15</td>
<td>91.70%</td>
<td>93.00%</td>
</tr>
<tr>
<td>20</td>
<td>92.40%</td>
<td>93.00%</td>
</tr>
<tr>
<td>25</td>
<td>93.00%</td>
<td>93.60%</td>
</tr>
</tbody>
</table>
Hours = When available, actual hours should be used. If actual hours are not available default hours are provided in table below for HVAC fan operation which varies by building type:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Total Fan Run Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>7235</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>8760</td>
</tr>
<tr>
<td>College</td>
<td>6103</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>7004</td>
</tr>
<tr>
<td>Elementary School</td>
<td>7522</td>
</tr>
<tr>
<td>Garage</td>
<td>7357</td>
</tr>
<tr>
<td>Grocery</td>
<td>7403</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>6345</td>
</tr>
<tr>
<td>High School</td>
<td>7879</td>
</tr>
<tr>
<td>Hospital - VAV econ</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - CAV econ</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - CAV no econ</td>
<td>8760</td>
</tr>
<tr>
<td>Hospital - FCU</td>
<td>8760</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>8706</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>8760</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>8760</td>
</tr>
<tr>
<td>Hotel/Motel - Guest</td>
<td>8760</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>8760</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>7505</td>
</tr>
<tr>
<td>Office - High Rise - VAV econ</td>
<td>6064</td>
</tr>
<tr>
<td>Office - High Rise - CAV econ</td>
<td>5697</td>
</tr>
<tr>
<td>Office - High Rise - CAV no econ</td>
<td>5682</td>
</tr>
<tr>
<td>Office - High Rise - FCU</td>
<td>6163</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>6288</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>6125</td>
</tr>
<tr>
<td>Religious Building</td>
<td>7380</td>
</tr>
<tr>
<td>Restaurant</td>
<td>7809</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>6890</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>6846</td>
</tr>
<tr>
<td>Warehouse</td>
<td>6786</td>
</tr>
<tr>
<td>Unknown</td>
<td>7100</td>
</tr>
</tbody>
</table>

ESF = Energy Savings Factor, the ESF for notched v-belt installation is assumed to be 2%
= the ESF for notched Synchronous Belt Installation is assumed to be 3.1%.

---

502 Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type.
503 Based on information found in Advanced Manufacturing Office, US DOE, “Replace V-Belts with Notched or Synchronous Drives”, (US Department of Energy Motor Systems Tip Sheet #5, DOE/GO-102012-3740, November 2012). V-belt drives can have a peak efficiency of 95% and synchronous belts operate at 98%, therefore ESF is (1 - 95%/98%) = 3.1%.
EXAMPLE

For example, a notched v-belt installation in an low rise office building RTU with a 5 HP NEMA premium efficiency motor using the default hours of operation, motor load and 89.5% motor efficiency;

\[
\Delta kWh = kW_{\text{connected}} \times \text{Hours} \times \text{ESF}
\]
\[
= ((\text{HP} \times 0.746 \text{ kW/HP} \times \text{Load Factor})/\text{Motor Efficiency}) \times \text{Hours} \times \text{ESF}
\]
\[
= ((5 \text{ HP} \times 0.746 \text{ kW/HP} \times 80\%) / 89.5\%) \times 6288 \times 2\%
\]
\[
= 419 \text{ kWh Savings}
\]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta kW = kW_{\text{connected}} \times \text{ESF}
\]

Where:

\[
kW_{\text{connected}} = \text{KW of equipment is calculated using motor efficiency.}
\]
\[
= (\text{HP} \times 0.746 \text{ kW/HP} \times \text{Load Factor})/\text{Motor Efficiency}
\]

Variables as provided above

EXAMPLE

For example, an office building RTU with a 5 HP NEMA premium efficiency motor using the default hours of operation, motor load and 89.5% motor efficiency;

\[
\Delta kW = kW_{\text{connected}} \times \text{ESF}
\]
\[
= ((\text{HP} \times 0.746 \text{ kW/HP} \times \text{Load Factor})/\text{Motor Efficiency}) \times \text{ESF}
\]
\[
= ((5 \text{ HP} \times 0.746 \text{ kW/HP} \times 80\%) / 89.5\%) \times 2\%
\]
\[
= 0.0667 \text{ kW Savings}
\]

NATURAL GAS SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A
MEASURE CODE: CI-HVC-NVBE-V03-180101

REVIEW DEADLINE: 1/1/2022
4.4.31 Small Business Furnace Tune-Up

**DESCRIPTION**

This measure is for a natural gas Small Business furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

This measure was developed to be applicable to the following program types: Small business.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure an approved technician must complete the tune-up requirements listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer’s recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer’s recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer’s
- Inspect duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer’s recommendations (if adjustments made, refer to ‘Small Commercial Programmable Thermostat Adjustment’ measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the tune up is 2 years.\(^{505}\)

**DEEMED MEASURE COST**

The incremental cost for this measure should be the actual cost of tune up.

**DEEMED O&M COST ADJUSTMENTS**

There are no expected O&M savings associated with this measure.

**LOADSHAPE**

Loadshape C04 - Commercial Electric Heating

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\(^{504}\) American Standard Maintenance for Indoor Units: http://www.americanstandardair.com/owner-support/maintenance.html

COINCIDENCE FACTOR

N/A

Algorithms

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \Delta \text{Therms} \times F_e \times 29.3 \]

Where:

\( \Delta \text{Therms} \) = as calculated below

\( F_e \) = Furnace Fan energy consumption as a percentage of annual fuel consumption

\[ F_e = 3.14\% \]

\( 29.3 \) = kWh per therm

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS SAVINGS

\[ \Delta \text{Therms} = (\text{Capacity} \times \text{EFLH} \times (((\text{Effbefore} + \text{Ei})/ \text{Effbefore}) – 1)) / 100,000 \]

Where:

\( \text{Capacity} \) = Furnace gas input size (Btu/hr)

\( = \) Actual

\( \text{EFLH} \) = Equivalent Full Load Hours for heating are provided in section 4.4 HVAC End Use

\( \text{Effbefore} \) = Efficiency of the furnace before the tune-up

\( = \) Actual

\( \text{EI} \) = Efficiency Improvement of the furnace tune-up measure

\( = \) Actual

\( 100,000 \) = Converts Btu to therms

Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.

\[ 506 \] \( F_e \) is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% \( F_e \). See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.
EXAMPLE

A 200 kBtu furnace in a Rockford low rise office records an efficiency prior to tune up of 82% AFUE and a 1.8% improvement in efficiency are tune up:

\[
\Delta \text{therms} = \frac{(200,000 \times 1428 \times ((0.82 + 0.018)/0.82) - 1))}{100,000}
\]

\[
= 62.3 \text{ therms}
\]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-FTUN-V02-160601

REVIEW DEADLINE: 1/1/2022
4.4.32 Combined Heat and Power

DESCRIPTION

The Combined Heat and Power (CHP) measure can provide energy savings within the State of Illinois through the development and operation of CHP projects. This measure is applicable for Conventional or Topping Cycle CHP systems, as well as Waste Heat-to-Power (WHHP) or Bottoming Cycle CHP systems. The measure will reduce the total Btu's of energy required to meet the end use needs of the facility.

It is recognized that CHP system design and configuration may be complex, and as such the calculation of energy savings may not be reducible to the equations within this measure. In such cases a more comprehensive engineering and financial analysis may be developed that more accurately incorporates the attributes of complex CHP configurations such as variable-capacity systems, and partial combined-cycle CHP systems. Where noted, the use of values that are determined through an external engineering analysis may be substituted by agreement between the participant, the program administrator and independent evaluator. This substitution of values does not eliminate ex post evaluation risk (retroactive adjustments to savings claims) that exists when using custom inputs.

This measure was developed to be applicable to the following program types: Retrofit (RF), New Construction (NC). If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Conventional or Topping Cycle CHP is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that utilizes a prime mover (reciprocating engine, gas turbine, micro-turbine, fuel cell, boiler/steam turbine combination) for the purpose of generating electricity and useful thermal energy (such as steam, hot water, or chilled water) where the primary function of the facility where the CHP is located is not to generate electricity for use on the grid. An eligible system must demonstrate a minimum total system efficiency of 60% (HHV) with at least 20% of the system’s total useful energy output in the form of useful thermal energy on an annual basis.

Measuring and Calculating Conventional CHP Total System Efficiency:

CHP efficiency is calculated using the following equation:

\[
CHP_{Efficiency}(HHV) = \frac{CHP_{thermal} \left[ \frac{Btu}{yr} \right] + E_{CHP} \left[ \frac{kWh}{yr} \right] \times 3.412 \left[ \frac{Btu}{kWh} \right]}{F_{totalCHP} \left[ \frac{kWh}{yr} \right]}
\]

Where:

- \( CHP_{thermal} \) = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.
- \( E_{CHP} \) = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.
- \( F_{totalCHP} \) = Total annual fuel consumed by the CHP system

For further definition of the terms, please see “Calculation of Energy Savings” Section below.

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507 Higher Heating Value (HHV): refers to the heating value of the fuel and is defined as the total thermal energy available, including the heat of condensation of water vapors, resulting from complete combustion of the fuel versus the Lower Heating Value (LHV) which assumes the heat of condensation is not available.
**Waste Heat-to-Power or Bottoming Cycle CHP** is defined as an integrated system that is located at or near the building or facility (on-site, on the customer side of the meter) that does one of the following:

- Utilizes exhaust heat from an industrial/commercial process to generate electricity (except for exhaust heat from a facility whose primary purpose is the generation of electricity for use on the grid); or
- Utilizes the pressure drop in an industrial/commercial facility to generate electricity through a backpressure steam turbine where the facility normally uses a pressure reducing valve (PRV) to reduce the pressure in their facility; or
- Utilizes the pressure reduction in natural gas pipelines (located at natural gas compressor stations) before the gas is distributed through the pipeline to generate electricity, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.

Since these types of systems utilize waste heat as their fuel, they do not have to meet any specific total system efficiency level (assuming they use no additional fossil fuel in their operation). If additional fuel is used onsite, it should be accounted for using the following methodology:

- Treat the portion of Waste-Heat-to-Power that does not require any additional fuel using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of Waste-Heat-to-Power that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section “Calculation of Energy Savings” for more details.
- Add the energy savings together.

These systems may export power to the grid.

**DEFINITION OF BASELINE EQUIPMENT**

**Electric Baseline:** The baseline facility would be a facility that purchases its electric power from the grid.

**Heating Baseline (for CHP applications that displace onsite heat):** The baseline equipment would be the boiler/furnace operating onsite, or a boiler/furnace meeting the baseline equipment defined in the High Efficiency Boiler (Section 4.4.10)/Furnace (Section 4.4.11) measures of this TRM.

**Cooling Baseline (for CHP applications that displace onsite cooling demands):** The baseline equipment would be the chiller (or chillers) operating onsite, or a chiller (or chillers) meeting the definition of baseline equipment defined in the Electric Chiller (Section 4.4.6) measure of this TRM.

**Facilities that use biogas or waste gas:** Facilities that use (but are not purchasing) biogas or waste gas that is not otherwise used, whether they are using biogas or waste gas only or a combination of biogas or waste gas and natural gas to meet their energy demands are also eligible for this measure. If additional fuel is purchased to power the CHP system, then the additional natural gas should be taken into account using the following methodology:

- Treat the portion of CHP system that does not require any additional fuel, or that requires additional fuel that would otherwise be wasted (e.g. flared), using the Waste-Heat-to-Power methodology outlined in this document.
- Treat the portion of CHP that requires additional fuel (if natural gas) using the Conventional CHP methodology outlined in this document. If the additional fuel is not natural gas, custom carbon equivalency calculations would be needed – refer to section “Calculation of Energy Savings” for more details.
- Add the energy savings together.

Consumption of any biogas or waste gas that would not otherwise being wasted (e.g., flared) will be accounted for in the overall net BTU savings calculations the same as for purchased natural gas.
DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Measure life is a custom assumption, dependent on the technology selected and the system installation.

DEEMED MEASURE COST

Custom installation and equipment cost will be used. These costs should include the cost of the equipment and the cost of installing the equipment. Equipment costs include, but are not limited to: prime mover, heat recovery system(s), exhaust gas treatment system(s), controls, and any interconnection/electrical connection costs.

The installations costs include labor and material costs such as, but not limited to: labor costs, materials such as ductwork, piping, and wiring, project and construction management, engineering costs, commissioning costs, and other fees.

Measure costs will also include the present value of expected maintenance costs over the life of the CHP system.

LOADSHAPE

Use Custom Loadshape. The loadshape should be obtained from the actual CHP operation strategy, based on the On-Peak and Off-Peak Energy definitions specified in Table 3.3 of “Section 3.5 Electrical Loadshapes” of the TRM.

COINCIDENCE FACTOR

Custom coincidence factor will be used. Actual value based on the CHP operation strategy will be used.

Algorithm

CALCULATION OF ENERGY SAVINGS

i) Conventional or Topping Cycle CHP Systems:

Step 1: (Calculating Total Annual Source Fuel Savings in Btus)

The first step is to calculate the total annual source fuel savings associated with the CHP installation, in order to ensure the CHP project produces positive total annual source fuel savings (i.e. reduction in source Btus):

\[ S_{\text{FuelCHP}} = \text{Annual fuel savings (Btu) associated with the use of a Conventional CHP system to generate the useful electricity output (kWh, converted to Btu) and useful thermal energy output (Btu) versus the use of the equivalent electricity generated and delivered by the local grid and the equivalent thermal energy provided by the onsite boiler/furnace.} \]

\[ = (F_{\text{grid}} + F_{\text{thermalCHP}}) - F_{\text{total CHP}} \]

Where:

\[ F_{\text{grid}} = \text{Annual fuel in Btu that would have been used to generate the useful electricity output of the CHP system if that useful electricity output was provided by the local utility grid.} \]

\[ = E_{\text{CHP}} * H_{\text{grid}} \]

Where:

\[ E_{\text{CHP}} = \text{Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.} \]

\[ 508 \text{ For complex systems this value may be obtained from a CHP System design/financial analysis study.} \]
\[
= ( \text{CHP}_{\text{capacity}} \times \text{Hours} ) - \text{E}_{\text{parasitic}}
\]

- \( \text{CHP}_{\text{capacity}} \) = CHP nameplate capacity
- \( \text{Hours} \) = Annual operating hours of the system
- \( \text{E}_{\text{parasitic}} \) = The electricity required to operate the CHP system that would otherwise not be required by the facility/process
- \( \text{H}_{\text{grid}} \) = Heat rate of the grid in Btu/kWh, based on the average fossil heat rate for the EPA eGRID subregion, adjusted to take into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)\(^{509}\). Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest). Also include any line losses.

\[ F_{\text{thermalCHP}} = \text{annual fuel in Btu that would have been used on-site by a boiler/furnace to provide the useful thermal energy output of the CHP system.} \]

\[ = \frac{\text{CHP}_{\text{thermal}}}{\text{Boiler}_{\text{eff}}} \text{ or } \frac{\text{CHP}_{\text{thermal}}}{\text{Furnace}_{\text{eff}}} \]

- \( \text{CHP}_{\text{thermal}} \) = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.
- \( \text{Boiler}_{\text{eff}} / \text{Furnace}_{\text{eff}} \) = Efficiency of the on-site Boiler/Furnace that is displaced by the CHP system or if unknown, the baseline equipment value stated in the High Efficiency Boiler (Section 4.4.10) measure or High Efficiency Furnace (Section 4.4.11) measure in this TRM.

\[ F_{\text{total CHP}} = \text{Total fuel in Btus consumed by the CHP system} \]

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\(^{509}\) These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct.

Refer to the latest EPA eGRID data. Current values, based on eGrid 2014 are:

- Non-Baseload RFC West: 9,346 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,157 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,931 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 10,209 Btu/kWh * (1 + Line Losses)

\(^{510}\) For complex systems this value may be obtained from a CHP System design/financial analysis study.
Step 2: (Savings Allocation to Program Administrators for Purposes of Assessing Compliance with Energy Savings Goals (Not for Use in Load Reduction Forecasting))

Savings claims are a function of the electric output of the CHP system ($E_{CHP}$), the used thermal output of the CHP system ($F_{thermalCHP}$), and the CHP system efficiency ($CHP_{Eff}(HHV)$). The percentages of electric output and used thermal output that can be claimed also differ slightly depending on whether the project was included in both electric\textsuperscript{511} and gas\textsuperscript{512} Energy Efficiency Portfolio Standard (EEPS)\textsuperscript{513} efficiency programs, only an electric EEPS program or only a gas EEPS program. The tables below provide the specific percentages of electric and/or thermal output that can be claimed under each of those three scenarios. These percentages apply only to cases in which natural gas is the fuel used by the CHP system. Saving estimates for systems using other fuels should be calculated on a custom basis. If the waste heat recovered from the CHP system is offsetting electric equipment, such as an absorption chiller offsetting an electric chiller, then the net change in electricity consumption associated with the electric equipment should be added to the allocated electric savings.

1) For systems participating in both electric EEPS and gas EEPS programs:

<table>
<thead>
<tr>
<th>CHP Annual System Efficiency</th>
<th>Allocated Electric Savings</th>
<th>Allocated Gas Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>65% of $E_{CHP}$ (kWh)</td>
<td>No gas savings</td>
</tr>
<tr>
<td>&gt;60% to 65%</td>
<td>65% of $E_{CHP}$ (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of $E_{CHP}$ in kWh)</td>
<td>No gas Savings</td>
</tr>
<tr>
<td>&gt;65%</td>
<td>70% of $E_{CHP}$ (kWh)</td>
<td>2.5% of $F_{thermal}$ (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 65%.</td>
</tr>
</tbody>
</table>

Example: System with measured annual system efficiency (HHV) of 70%: Electric savings (kWh) = 70% of $E_{CHP}$ measured over 12 months, and Gas savings (therms) = 12.5% of $F_{thermal}$ measured over 12 months (70% - 65% = 5 x 2.5% = 12.5%)

2) For systems participating in only an electric EEPS program:

<table>
<thead>
<tr>
<th>CHP Annual System Efficiency</th>
<th>Allocated Electric Savings</th>
<th>Allocated Gas Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td>65% of $E_{CHP}$ (useful electric output of CHP system in kWh)</td>
<td>No gas Savings</td>
</tr>
<tr>
<td>Greater than 60%</td>
<td>65% + one percentage point increase for every one percentage point increase in CHP system efficiency (no max)</td>
<td>No gas Savings</td>
</tr>
</tbody>
</table>

Example: System with measured annual fuel use efficiency of 75%: Electric savings (kWh) = 65% + 15% = 80% of $E_{CHP}$ measured over 12 months (15% = 1% for every 1% increase in system efficiency). No gas savings (therms).

\textsuperscript{511} 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B
\textsuperscript{512} 220 ILCS 5/8-104
\textsuperscript{513} As used in this measure characterization, EEPS programs are defined as those energy efficiency programs implemented pursuant to Sections 8-103, 8-104, and 16-111.5B of the Illinois Public Utilities Act. Technically, EEPS programs pertain to energy efficiency programs implemented pursuant to 220 ILCS 5/8-103 and 220 ILCS 5/8-104. However, for simplicity in presentation, this measure defines EEPS programs as also including those programs implemented pursuant to 220 ILCS 5/16-111.5B (these programs are funded through the same energy efficiency riders established pursuant to Section 8-103).
3) For systems participating in only a gas EEPS program:

<table>
<thead>
<tr>
<th>CHP Annual System Efficiency (HHV)</th>
<th>Allocated Electric Savings</th>
<th>Allocated Gas Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>60% or greater</td>
<td>No electric savings</td>
<td>2.5% of $F_{thermal}$ (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 60%</td>
</tr>
</tbody>
</table>

Example: System with measured annual system efficiency (HHV) of 70%: No Electric savings (kWh). Gas savings (therms) = 25% of $F_{thermal}$ measured over 12 months (70% - 60% = 10 X 2.5% = 25%)

Conventional or topping cycle CHP systems virtually always require an increase in the use of fuel on-site in order to produce electricity. Different jurisdictions and experts across the country have employed and/or put forward a variety of approaches\(^514\) to address how increased on-site fuel consumption should be reflected in the attribution of electric savings to CHP systems. The approach reflected in the tables above is generally consistent — for CHP systems consuming natural gas — with approaches recently put forward by the Southwest Energy Efficiency Project (SWEEP) and Institute for Industrial Productivity (IIP) that determine reduced electric savings based on the equivalent amount of carbon dioxide generated from the increased fuel used\(^515\).

There are a variety of ways one could treat the potential for gas utilities to claim savings from CHP projects in their EEPS portfolios. For projects in which a natural gas EEPS program is involved, the tables above treat savings from CHP installations in two steps: (1) a fuel-switch from electricity to natural gas (i.e. using more natural gas to eliminate the need to generate as much electricity on the grid); and (2) possible increases in CHP efficiency above a “benchmark” level. When both electric EEPS and natural gas EEPS programs are involved in a project, the program administrator claims all the electricity savings associated with a fuel-switch up to a “benchmark” 65% efficient CHP system. All the savings associated with increasing CHP efficiencies above that benchmark level are allocated to natural gas (e.g. if the CHP efficiency is 75%, the natural gas savings associated with an increase in CHP efficiency from 65% to 75% are allocated to natural gas). That is consistent with the notion that CHP efficiency typically increases primarily by increasing the use of the thermal output of the system (increasing the displacement of baseline gas use). For projects that involve only a natural gas EEPS program, the “benchmark” above which the gas utility can claim savings is lowered to 60%.

ii) Waste-Heat-to-Power CHP Systems:

**Electric Energy Savings:**

\[ \Delta \text{kWh} = E_{CHP} \]

\(^{514}\) Approaches range from ignoring the increased gas use entirely (i.e., no “penalty”) to applying approximately 40-60% “penalties”, depending on the CHP efficiency and based on the equivalent grid kWh that the increased gas use represents.

\(^{515}\) Consider, for example, a hypothetical CHP system that produces 5 million kWh annually, consumes 50 million kBtu of gas annual to generate that electricity (i.e. electric efficiency of approximately 34.8% HHV), reduces on-site gas use for space heating by 26 million kBtu of gas (i.e. equivalent to approximately 81.5% CHP thermal output utilization displacing gas used in a 70% efficient space heating boiler) and has a total annual CHP efficiency of 70.6% HHV. In this example, the net increase in on-site gas use is 24 million kBtu. At a carbon dioxide emission rate of 53.06 kg/MMBtu for burning natural gas, that translates to an increase in on-site carbon dioxide emissions of 1404 tons per year. At an estimated marginal emission rate of 1.098 tons of carbon dioxide per MWh in Illinois, that is equivalent to electric grid production of approximately 1.28 million kWh, or penalty of about 25.6% of the CHP system’s electrical output if a precise calculation of carbon equivalency was utilized to assign savings. In comparison, the simplified table above would entitle an electric utility to claim savings equal to 75.6% of the electric output (i.e. a penalty of 24.4% of electrical output) if it was the only utility promoting the system. In a gas and electric example, the electric savings claimed would be 70% of the production (a penalty of 30% of the CHP system’s electrical output) and 12.5% of the recovered thermal output, equivalent to 2.23 million kBtu. The difference between the electric only scenario and the electric and gas, on the electric side, is 5% of the electric output or 250,000 kWh, which would require 2.45 million kBtu input at an efficiency of 34.8% HHV.
Where:

\[ E_{CHP} = \text{Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.} \]

\[ = \text{Custom input} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = CF \cdot \text{CHP capacity} \]

Where:

\[ CF = \text{Summer Coincidence factor. This factor should also consider any displaced chiller capacity}^{516} \]

\[ = \text{Custom input} \]

\[ \text{CHP capacity} = \text{CHP nameplate capacity} \]

\[ = \text{Custom input} \]

**NATURAL GAS ENERGY SAVINGS:**

\[ \Delta \text{Therms} = F_{\text{thermalCHP}} / 100,000 \]

Where:

\[ F_{\text{thermalCHP}} = \text{Net savings in annual purchased fuel in Btu, if any, that would have been used on-site by a boiler/furnace to provide some or all of the useful thermal energy output of the CHP system}^{517}. \]

\[ 100,000 = \text{Conversion factor for Btu to therms} \]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Custom estimates of maintenance costs that will be incurred for the life of the measure will be used. Maintenance costs vary with type and size of the prime mover. These costs include, but are not limited to:

- Maintenance labor
- Engine parts and materials such as oil filters, air filters, spark plugs, gaskets, valves, piston rings, electronic components, etc. and consumables such as oil
- Minor and major overhauls

For screening purposes, the US EPA has published resource guides that provide average maintenance costs based on CHP technology and system size\(^518\).

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\(^{516}\) If some or all of the existing electric chiller peak demand is no longer needed due to new waste heat powered chillers (e.g., absorption), the coincidence factor should be adjusted appropriately.

\(^{517}\) In most cases, it is expected that waste-heat-to-power systems will not provide any new net useful thermal energy output, since the CHP system will be driven by thermal energy that was otherwise being wasted. If additional natural gas or other purchased energy is used onsite, it should be properly accounted for.

**Cost-Effectiveness Screening and Load Reduction Forecasting**

For the purposes of forecasting load reductions due to CHP projects per Section 16-111.5B, changes in site energy use at the customer’s meter – reduced consumption of utility provided electricity – adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

For the purposes of screening a CHP measure application for cost-effectiveness, changes in site energy use – reduced consumption of utility provided electricity and the net change in consumption of fuel – should be used. In general, the benefit and cost components used in evaluating the cost-effectiveness of a CHP project would include at least the following terms:

- **Benefits:** \( E_{CHP} + \Delta kW + F_{thermal_{CHP}} \)
- **Costs:** \( F_{total_{CHP}} + CHP_{COSTS} + O&M_{COSTS} \)

Where:

- \( CHP_{Costs} \) = CHP equipment and installation costs as defined in the “Deemed Measure Costs” section
- \( O&M_{Costs} \) = CHP operations and maintenance costs as defined in the “Deemed O&M Cost Adjustment Calculation” section

**Measure Code:** CI-HVC-CHAP-V02-180101

**Review Deadline: 1/1/2020**
4.4.33 Industrial Air Curtain

**DESCRIPTION**

This measure applies to buildings with exterior entryways that utilize overhead doors. All other air curtain applications, such as through sliding door entryways or conventional foot-traffic entryways, require custom analysis as air curtain designs must often accommodate other factors that may change their effectiveness.

The use of overhead doors within exterior entryways during the heating season leads to the exfiltration of warm air from the upper portion of the door opening and the infiltration of colder air from the lower portion of the door opening. This results in increased heating energy use to compensate for heat losses every time a door is opened. By reducing heat losses, air curtains can also enhance the physical comfort of employees or customers near the entryway as there will be reduced temperature fluctuations when the door is opened and closed. In addition, in some cases excess heating capacity may be installed in buildings to meet this larger heating load. The addition of air curtains to exterior entryways that currently utilize overhead doors will result in energy savings and enhanced personal comfort, and also possibly in reduced equipment sizing and corresponding costs.

The primary markets for this measure are commercial and industrial facilities with overhead doors in exterior entryways, including but not limited to the following building types: retail, manufacturing, and warehouse (non-refrigerated).

**Limitations**

- For use in conditioned spaces with an overhead door in an exterior entryway. This measure does include other door types such as doorways to commercial spaces such as retail.
- This measure should only be applied to spaces in which the overhead door separates a conditioned space and an unconditioned space.
- Installation must follow manufacturer recommendations to attain proper air velocity, discharge angle down to the floor level, and unit position.
- Certain heating systems may not be a good fit for air curtains, such as locations with undersized heating capacity. In these cases, the installation of an air curtain may not effectively reduce heating system cycling given the inappropriately sized heating capacity.
- Buildings with slightly positive to slightly negative (~5 Pa to -10 Pa). For all other scenarios, custom analysis is recommended.
- Measure assumes that wind speeds at near ground level are less than or equal to 12 mph for 90% of the heating or cooling season. For areas with more extreme weather, custom analysis is necessary.
- Note: for cost effectiveness, it is recommended that minimum door open times should be approximately 15 hours per week.\(^{519}\)

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

The following methodology is highly complex and requires significant data collection. It is hoped that simplifying steps can be made in future iterations based on continued metering and evaluation of installations. Also the data collected through implementing the measure in the way currently drafted will aid in simplifying efforts at a future date.

**DEFINITION OF EFFICIENT EQUIPMENT**

Overhead air curtains designed for commercial and industrial applications that have been tested and certified in accordance with ANSI/AMCA 220 and installed following manufacturer guidelines. Measure is for standard models without added heating.

**DEFINITION OF BASELINE EQUIPMENT**

No air curtain or other currently installed means to effectively reduce heat loss and air mixing during door openings, such as a vestibule or strip curtain.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 years.\(^{520}\)

**DEEMED MEASURE COST**

The incremental capital cost for overhead air curtains for exterior entryways are as follows, with an added average installation cost approximately equal to the capital cost.\(^{521}\)

<table>
<thead>
<tr>
<th>Door Size</th>
<th>Capital Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>8’w x 8’h</td>
<td>$3,600</td>
</tr>
<tr>
<td>10’w x 10’h</td>
<td>$4,500</td>
</tr>
<tr>
<td>10’w x 12’h</td>
<td>$5,400</td>
</tr>
<tr>
<td>12’w x 14’h</td>
<td>$8,000</td>
</tr>
<tr>
<td>16’w x 16’h</td>
<td>$13,300</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

Heating Season: If electric heating, use Commercial Electric Heating Loadshape: C04. Otherwise, N/A

Cooling Season: Commercial Cooling Loadshape C03. Or, if applicable, use Commercial Electric Heating and Cooling Loadshape C05.

**COINCIDENCE FACTOR**

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \]

\[ = 91.3\% \] \(^{522}\)

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \]

\[ = 47.8\% \] \(^{523}\)

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

The following formulas provide a methodology for estimating cooling load (kWh) and heating load (therm) savings associated with the installation of air curtains on exterior entryways such as a single door or loading bay. This algorithm is based on the assumption that therm savings are directly related to the difference in cooling or heating losses due to infiltration or exfiltration through an entryway before and after the installation of an AMCA certified air curtain. Energy savings are assumed to be the result of a reduction of natural infiltration effects due to wind and thermal forces and follow the calculation methodology outlined by the ASHRAE Handbook.\(^{524}\)

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\(^{521}\) Based on manufacturer interviews and air curtain specification sheets.

\(^{522}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

\(^{523}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

assumes that the air curtain is appropriately sized and commissioned to be effective in mitigating infiltration of winds of up to 12 mph for at least 90% of the year (based on manufacturer literature and TMY3 wind speed ranges at near ground level for Illinois). Additionally, this measure assumes the HVAC systems are appropriately balanced such that the maximum pressure differential between indoor air and outdoor air is within the range of 5 Pa < ΔP < -10 Pa. Custom analysis is necessary if building pressurization exceeds this range. However, while effectiveness decreases, some studies suggest that air curtains outperform vestibules and single door construction for negatively pressurized buildings with a ΔP of above -30 Pa.

This algorithm allows either actual inputs or provides estimates if actual data is not available. All weather dependent values are derived from TMY3 data for the closest weather station to those locations defined elsewhere in the Illinois TRM (which are based on 30 year climate normals). If TMY3 weather station data was not available for the data used in the Illinois TRM, the next closest weather station was used. It is assumed that weather variations are negligible between the weather stations located within the same region. This approach was followed as the air curtain algorithm has a number of weather dependent variables which are all calculated in relation to the heating season or cooling season as defined by the balance point temperature deemed appropriate for the facility. All weather dependent data is based on TMY3 data and is listed in tables by both climate zone and balance point temperature, which is then normalized to the Illinois TRM climate zoned HDD/CDD definitions unless otherwise noted.

**Electric Energy Savings**

\[
\Delta kWh_{cooling} = \left(\frac{Q_{tbc} - Q_{tac}}{EER - (HP * 0.7457)}\right) * t_{open} * CD
\]

\[
\Delta kWh_{HP_{heating}} = \left(\frac{Q_{tbc} - Q_{tac}}{HSPF - (HP * 0.7457)}\right) * t_{open} * HD
\]

\[
\Delta kWh_{Gas_{heating}} = -(HP * 0.7457) * t_{open} * HD
\]

Where:

- \(Q_{tbc}\) = rate of total heat transfer through the open entryway, before air curtain (kBtu/hr)
- \(Q_{tac}\) = rate of total heat transfer through the open entryway, after air curtain (kBtu/hr)
  (see calculation in ‘Heat Transfer Through Open Entryway with/without Air Curtain’ sections below)
- EER = energy efficiency ratio of the cooling equipment (kBtu/kWh)
  = Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates
- HP = Input power for air curtain (hp)
  = Actual value. If actual value not available, use the following estimates based on manufacturer specs

<table>
<thead>
<tr>
<th>Door Size</th>
<th>Fan HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>8’w x 8’h</td>
<td>1</td>
</tr>
<tr>
<td>10’w x 10’h</td>
<td>1.5</td>
</tr>
<tr>
<td>10’w x 12’h</td>
<td>4</td>
</tr>
<tr>
<td>12’w x 14’h</td>
<td>6</td>
</tr>
</tbody>
</table>

---


### Industrial Air Curtain

<table>
<thead>
<tr>
<th>Door Size</th>
<th>Fan HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>16'w x 16'h</td>
<td>12</td>
</tr>
</tbody>
</table>

0.7457 = unit conversion factor, brake horsepower to electric power (kW/HP)

t\(_{open}\) = average hours per day the door is open (hr/day)

= Actual or user defined estimated value.

CD = cooling days per year, total days in year above balance point temperature (day)

= use table below to select the best value for location\(^{528}\)

### Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>CD (Balance Point Temperature)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>194</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>194</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>214</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>258</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>222</td>
</tr>
</tbody>
</table>

HSPF = Heating System Performance Factor of heat pump equipment

= Actual. If unknown, use the table C403.2.3(2) in IECC 2012 (or IECC 2015 if through new construction) to assume values based on code estimates

HD = heating days per year, total days in year above balance point temperature (day)

= use table below to select an appropriate value\(^{529}\):

### Heat Transfer Through Open Entryway without Air Curtain (Cooling Season)

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>HD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>142</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>150</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>125</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>101</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>103</td>
</tr>
</tbody>
</table>


Note that cooling days (CD) are calculated by first determining its value from the TMY3 data associated with the appropriate weather station as defined by and used elsewhere in the Illinois TRM. Using the TMY3 outdoor air dry bulb hourly data, the annual hours are totaled for every hour that the outdoor air dry bulb temperature is above a designated zero heat loss balance point temperature or base temperature for cooling. For commercial and industrial (C&I) buildings, a base temperature for heating of 55 °F is designated in the Illinois TRM, but building specific base temperatures are recommended for large C&I projects. Additionally, the TRM uses a 30-year normal data for degree-days while the CD calculation was based on TMY3 data; in order to account for this, calculations of CD were also normalized by the ratio of CDD to align the calculated values more closely with the TRM.

\(^{529}\) Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.
\[ Q_{\text{bc}} = 4.5 \times \text{CFM}_{\text{tot}} \times (h_{\text{oc}} - h_{\text{ic}}) / (1,000 \text{ Btu/kBtu}) \]

Where:

4.5 = unit conversion factor with density of air: 60 min/hr * 0.075 lbm/ft³ (lb*min/(ft*hr))

\( \text{CFM}_{\text{tot}} \) = Total air flow through entryway (cfm), see calculation below

\( h_{\text{oc}} \) = average enthalpy of outside air during the cooling season (Btu/lb)

\( h_{\text{ic}} \) = average enthalpy of indoor air, cooling season (Btu/lb)

- use the below table to determine the approximate outdoor air enthalpy associated with an indoor temperature setpoint and climate zone.\(^{530} \)

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>( h_{\text{oc}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>67 °F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>31.6</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>32.0</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>32.9</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>33.5</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>34.6</td>
</tr>
</tbody>
</table>

- use the below table to determine the approximate indoor air enthalpy associated with an indoor temperature setpoint in indoor relative humidity.

<table>
<thead>
<tr>
<th>Relative Humidity (%)</th>
<th>( h_{\text{ic}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>67 °F</td>
</tr>
<tr>
<td>60</td>
<td>25.5</td>
</tr>
<tr>
<td>50</td>
<td>23.9</td>
</tr>
<tr>
<td>40</td>
<td>22.3</td>
</tr>
</tbody>
</table>

- an estimate 26.6 Btu/lb associated with the 72 °F and 50% indoor relative humidity case can be used as an approximation if no other data is available. For other indoor temperature setpoints and RH, enthalpies may be interpolated.

The total airflow through the entryway, \( \text{CFM}_{\text{tot}} \), includes both infiltration due to wind as well as thermal forces, as follows:

\[ \text{CFM}_{\text{tot}} = \sqrt{(\text{CFM}_{\text{w}})^2 + (\text{CFM}_{\text{t}})^2} \]

Where:

\( \text{CFM}_{\text{w}} \) = Infiltration due to the wind (cfm)

\( \text{CFM}_{\text{t}} \) = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

\[ \text{CFM}_{\text{w}} = (v_{\text{wc}} * C_{\text{wc}}) * C_{\text{r}} * A_{\text{d}} * (88 \text{ fpm/mph}) \]

Where:

\(^{530}\) Average enthalpies were estimated following ASHRAE guidelines for perfect gas relationships for dry air associated with hourly TMY3 data. Error! Reference source not found. Enthalpies were then averaged for all values associated with a dry-bulb outdoor air temperature that exceeded the indoor air temperature setpoint. Other enthalpy values may be interpolated for indoor air temperature setpoints not represented in the table. Note that while outdoor air enthalpies increase with higher temperature setpoints, the change in enthalpy from indoor to outdoor will decrease.
\[ \nu_{wc} = \text{average wind speed during the cooling season based on entryway orientation (mph)} \]

= use the below table to for the wind speed effects based on climate zone and entryway orientation:\[^{531}\]

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Climate Zone -Weather Station/City} & \text{N} & \text{E} & \text{S} & \text{W} \\
\hline
1 - Rockford AP / Rockford & 4.2 & 4.1 & 4.7 & 4.8 \\
2 - Chicago O'Hare AP / Chicago & 4.7 & 4.5 & 5.4 & 4.6 \\
3 - Springfield #2 / Springfield & 4.1 & 3.7 & 6.0 & 5.0 \\
4 - Belleville SIU RSCH / Belleville & 3.3 & 2.7 & 3.8 & 4.2 \\
5 - Carbondale Southern IL AP / Marion & 3.1 & 2.9 & 4.4 & 3.8 \\
\hline
\end{array}
\]

\[ C_{wc} = \text{wind speed correction factor due to wind direction in cooling season, (\%)} \]

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the cooling season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for cooling applications.

\[
\begin{array}{|c|c|c|c|c|}
\hline
\text{Climate Zone -Weather Station/City} & \text{N} & \text{E} & \text{S} & \text{W} \\
\hline
1 - Rockford AP / Rockford & 0.18 & 0.13 & 0.30 & 0.31 \\
2 - Chicago O'Hare AP / Chicago & 0.18 & 0.17 & 0.36 & 0.26 \\
3 - Springfield #2 / Springfield & 0.17 & 0.12 & 0.46 & 0.21 \\
4 - Belleville SIU RSCH / Belleville & 0.21 & 0.15 & 0.35 & 0.16 \\
5 - Carbondale Southern IL AP / Marion & 0.18 & 0.15 & 0.37 & 0.11 \\
\hline
\end{array}
\]

Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

\[ C_v = \text{effectiveness of openings,} \]

= 0.3, assumes diagonal wind\[^{20}\]

\[ A_d = \text{area of the doorway (ft}^2) \]

= user defined

The infiltration due to thermal forces is calculated as follows:

\[
\text{CFM}_t = A_d * C_{dc} * (60 \text{ sec/min}) * \sqrt{2 * g * H/2 * (T_{oc} - T_{ic}) / (459.7 + T_{oc})}
\]

Where:

\[ C_{dc} = \text{the discharge coefficient during the cooling season\[^{532}\]} \]

= 0.4 + 0.0025 * |T_{ic} - T_{oc}| 

= 0.42, Illinois average at indoor air temp of 72°F 

Note, values for \( C_{dc} \) show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

\[^{531}\] Average wind speeds are calculated based on the TMY3 wind speed data. Because this data is collected at an altitude of 33 ft, wind speed is approximated for a 5 ft level based on ASHRAE Handbook guidelines using the urban/suburban parameters for adjusting wind speed based on altitude (\( \frac{\nu}{\nu_{33}} = 1200, \frac{\nu}{\nu_{33}} = 0.22 \). ASHRAE, “Airflow Around Buildings,” in 2013 ASHRAE Handbook – Fundamentals (2013): p 24.3

\( g \) = acceleration due to gravity
\( = 32.2 \text{ ft/sec}^2 \)

\( H \) = the height of the entryway (ft)
\( = \) user input

\( T_{ic} \) = Average indoor air temperature during cooling season
\( = \) User input, can assume indoor cooling temperature set-point

\( T_{oc} \) = Average outdoor temp during cooling season (°F)
\( = \) the average outdoor temperature is dependent on the CD period and zone. As such, the following table may be used for average outdoor temperature during the cooling period:

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>( T_{oc} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>62 °F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>72.9</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>72.9</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>73.7</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>74.9</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>75.1</td>
</tr>
</tbody>
</table>

\[ 459.7 \] = conversion factor from °F to °R
\( = \) calculation requires absolute temperature for values not calculated as a difference of temperatures.

**Heat Transfer Through Open Entryway with Air Curtain (Cooling Season)**

\[ Q_{tac} = Q_{tb} \times (1 - E) \]

Where:

\( E \) = the effectiveness of the air curtain (%)
\( = 0.60 \)

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = (\Delta kWh_{cooling} / (CD * 24)) \times CF \]

Where:

\( CF_{SSP} \) = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
\( = 91.3\% \)

\( CF_{PJM} \) = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

---

533 Based on binned data from TMY3 & adjusted bracketed thermostat setpoint temperatures. Interpolate other values as needed.
535 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.
= 47.8%  

**NATURAL GAS SAVINGS**

Natural gas savings, Δtherms, associated with reduced infiltration through an entryway during the heating season are calculated by determining the difference between heat loss through the entryway before and after the installation of the air curtain.

\[
\Delta \text{therms} = (Q_{bc} - Q_{ac}) \times t_{\text{open}} \times \text{HD} / \eta
\]

Where:

- \( Q_{bc} \) = rate of sensible heat transfer through the open entryway, before air curtain (therm/hr)
- \( Q_{ac} \) = rate of sensible heat transfer through the open entryway, after air curtain (therm/hr)
- \( t_{\text{open}} \) = average hours per day the door is open (hr/day)
- \( \text{HD} \) = heating days per year, total days in year above balance point temperature (day)

### Heat Transfer Through Open Entryway without Air Curtain (Heating Season)

\[
Q_{bc} = (1.08 \text{ Btu}/(\text{hr*}^\circ\text{F}*\text{cfm})) \times \text{CFM}_{\text{tot}} \times (T_{ih} - T_{oh}) / (100,000 \text{ Btu/therm})
\]

Where:

- 1.08 = sensible heat transfer coefficient (specific heat of air and unit conversions)
- \( \text{CFM}_{\text{tot}} \) = Total air flow through entryway (cfm)
- \( T_{ih} \) = Average indoor air temperature during heating season
- \( T_{oh} \) = Average outdoor temp during heating season (°F)

---

536 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

537 Note that Heating Days (HD) are calculated following the same approach outlined in the Cooling Days section.
The total airflow through the entryway, $\text{CFM}_{\text{tot}}$, includes both infiltration due to wind as well as thermal forces, as follows:

$$
\text{CFM}_{\text{tot}} = \sqrt{(\text{CFM}_w)^2 + (\text{CFM}_t)^2}
$$

Where:

- $\text{CFM}_w$ = Infiltration due to the wind (cfm)
- $\text{CFM}_t$ = Infiltration due to thermal forces (cfm)

The infiltration due to the wind is calculated as follows:

$$
\text{CFM}_w = (v_{wh} * C_{wh}) * C_v * A_d * (88 \text{ fpm/mph})
$$

Where:

- $v_{wh}$ = average wind speed during the heating season (mph)

= similar to cooling season wind speed assumptions, use the following table to determined average wind speed based on entryway orientation:

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>Avg Outdoor Air Temp - Heating Season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 °F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>26.3</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>29.4</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>29.4</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>31.7</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>32.5</td>
</tr>
</tbody>
</table>

$C_{wh}$ = wind speed correction factor due to wind direction in heating season, (%)

= because wind direction is not constant, a wind speed correction factor is used to adjust for the amount of time during the heating season prevailing winds can be expected to impact the entryway. Use the following table to determine the correct wind speed correction factor for the heating applications.

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>Entryway Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>5.0</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>5.5</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>5.0</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>4.3</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>4.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>Entryway Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>0.18</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>0.21</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>0.21</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>0.31</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>0.31</td>
</tr>
</tbody>
</table>
Note that correction factors do not add up to 1 (100%). This is attributed to periods of calm winds.

\[ C_v = \text{effectiveness of openings}, \]
\[ = 0.3, \text{assumes diagonal wind}^{24} \]
\[ A_d = \text{area of the doorway (ft}^2) \]
\[ = \text{user input} \]

The infiltration due to thermal forces is calculated as follows:

\[ \text{CFM}_t = A_d \times C_{dh} \times (60 \text{ sec/min}) \times \sqrt{2 \times g \times H / (2 \times (T_{ih} - T_{oh}) / (459.7 + T_{ih}))} \]

Where:

\[ C_{dh} = \text{the discharge coefficient during the heating season} \]
\[ = 0.4 + 0.0025 \times |T_{ih} - T_{oh}| \]
\[ = 0.49, \text{Illinois average at indoor air temp of 72°F} \]

Note, values for \( C_{dh} \) show little variation due to balance point temperature, indoor air temperature, and climate zone. As such, if estimating results, the Illinois average value may be used as a simplification.

\[ g = \text{acceleration due to gravity} \]
\[ = 32.2 \text{ ft/sec}^2 \]

\[ H = \text{the height of the entryway (ft)} \]
\[ = \text{user defined} \]

**Heat Transfer Through Open Entryway without Air Curtain (Heating Season)**

\[ Q_{bc} = Q_{bc} \times (1 - E) \]

Where:

\[ E = \text{the effectiveness of the air curtain (%)} \]
\[ = 0.60^{538} \]

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The air curtain would need to be regularly serviced and commissioned to ensure that it is appropriately operating. This is estimated at a cost of $150^{539}.

**MEASURE CODE: CI-MSC-AIRC-V01-160601**

**REVIEW DEADLINE: 1/1/2022**

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^{538} Assumed conservative estimate based on referenced study results and ASHRAE 2004 effectiveness range of 60-80% for air curtains. Jaramillo, Julian, et. Al. “Application of Air Curtains in Refrigerated Chambers,” International Refrigeration and Air-Conditioning Conference, Purdue University e-Pubs (July 14-17, 2008): http://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1972&context=iracc

^{539} Assumes approximately 1 hour of maintenance (include cleaning out filters, greasing, and checking that the designed angle of attack on the blower nozzle is at the designed position) based on manufacturer input and product spec sheets.
4.4.34 Destratification Fan

**DESCRIPTION**

This measure applies to buildings with high bay ceiling construction without fans currently installed for the purpose of destratifying air. There is also a separate measure for destratification fans as applied to agricultural settings (“High Volume Low Speed Fans”). All other destratification fan applications require custom analysis.

Air stratification leads to higher temperatures at the ceiling and lower temperatures at the ground. During the heating season, destratification fans improve air temperature distribution in a space by circulating warmer air from the ceiling back down to the floor level, thereby enhancing comfort and saving energy. Energy savings are realized by a reduction of heat loss through the roof-deck and walls as a result of a smaller temperature differential between indoor temperature and outdoor air.

Note that further, but limited, empirical evidence suggests that improved air mixing due to destratification would also result in shorter heating system runtimes due to warmer air reaching the thermostat level sooner, and possibly even allow a facility to lower the thermostat set point while maintaining a similar level of occupant comfort. This is supported by measured data in which an increase in temperatures was observed at the thermostat (5 foot level) level when air is destratified, resulting in an approximate temperature increase at the 5 foot level in the range of 1 - 3°F. This measure does not currently attempt to quantify the potential impacts of air mixing from destratification; however, it should be noted that additional therms savings may be possible.

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

**Limitations**

- For use in conditioned, high bay structures. Recommended minimum ceiling height of 20 ft.
- This measure should only be applied to spaces in which the ceiling is subject to heat loss to outdoor air (i.e., single story or top floor spaces) and where there is sufficient space to allow for appropriate spacing of the fans. Other applications require custom analysis.
- Installation must follow manufacturer recommendations sufficient to effectively destratify the entire space. Please see calculation of effective area, \( A_{eff} \), in the therms savings algorithm as a check if this criteria is met. Otherwise, custom calculation is necessary.
- Measure does not currently support facilities with night setbacks on heating equipment. Custom analysis is needed in this case.
- Certain heating systems may not be a good fit for destratification fans, such as locations with: high velocity vertical throw unit heaters, radiant heaters, and centralized forced air systems. In these cases, measured evidence of stratification should be confirmed and custom analysis may be necessary.

**DEFINITION OF EFFICIENT EQUIPMENT**

High Volume, Low Speed (HVLS) fans with a minimum diameter of 14 ft with Variable Speed Drive (VSD) installed. Note that bell-shaped fans are currently excluded from this measure due to limited validation of the technology available. Further verification of effectiveness compared to HVLS is needed. A manufacturer of bell shaped fans indicates that four bell-shaped fans provide an equivalent effective area as a typical HVLS fan. However, there is a need for further review of bell shaped fan field test data supporting manufacturer claims regarding comparable effectiveness to HVLS technologies.

---

541 Ibid.
**DEFINITION OF BASELINE EQUIPMENT**
No destratification fans or other means to effectively mix indoor air.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The expected measure life is assumed to be 10 years\(^{542}\).

**DEEMED MEASURE COST**
Measure cost = [incremental cost of HVLS fans] + [installation costs (including materials and labor)]
The incremental capital cost for HVLS fans are as follows\(^{543}\):

<table>
<thead>
<tr>
<th>Fan Diameter (ft)</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>$6,600</td>
</tr>
<tr>
<td>16</td>
<td>$6,650</td>
</tr>
<tr>
<td>18</td>
<td>$6,700</td>
</tr>
<tr>
<td>20</td>
<td>$6,750</td>
</tr>
<tr>
<td>22</td>
<td>$6,800</td>
</tr>
<tr>
<td>24</td>
<td>$6,850</td>
</tr>
</tbody>
</table>

Since installation cost is depended on a variety of factors, this is a custom entry. Actual costs should be used.

**LOADSHAPE**
Loadshape C04: Commercial Electric Heating.

**COINCIDENCE FACTOR**
N/A due to no savings attributable to cooling during the summer peak period.

**Algorithm**

**CALCULATION OF SAVINGS**
The following formulas provide a methodology for estimating heating load savings associated with destratification fan use. This algorithm is based on the assumption that savings are directly related to the difference in heat loss through the envelope before and after destratification.

**ELECTRIC ENERGY SAVINGS**
The algorithm for this measure was developed for natural gas heating applications, however, for electric heating applications, the same methodology presented in the Natural Gas Savings Section may be used with the standard conversion factor from therms to kWh of 29.31 kWh/therm and an equipment efficiency as follows:


\(^{543}\) Costs were obtained from manufacturer interviews and are based off of average or typical prices for base model HVLS fans. Costs include materials and labor to install the fans and tie fans into an existing electrical supply located near the fan.
Regardless of how the building is heated, the energy consumption of the fans must be accounted for. If the building is electrically heated, fan energy shall be subtracted from the savings as calculated above. If the building is heated with natural gas, this shall represent an electric penalty, i.e., an increase in consumption. This is calculated as follows:

\[
\Delta kWH = (W_{fan} * N_{fan}) * t_{eff}
\]

Where:
- \(W_{fan}\) = fan input power (kW)
- \(N_{fan}\) = number of fans
- \(t_{eff}\) = effective annual operation time, based on balance point temperature (hr)

\[\Delta kWH = (W_{fan} * N_{fan}) * t_{eff}\]

\[= \text{fan input power (kW)} \times \text{number of fans} \times \text{effective annual operation time (hr)}\]

\[\text{SUMMER COINCIDENT PEAK DEMAND SAVINGS}\]

N/A

\[\text{NATURAL GAS ENERGY SAVINGS}\]

\[\Delta \text{Therms} = \left[ (\Delta Q_r + \Delta Q_w) \times t_{eff} \right] / (100,000 \times \eta)\]

Where:
- \(\Delta Q_r\) = the heat loss reduction through the roof due to the destratification fan (Btu/hr)
- \(\Delta Q_w\) = the heat loss reduction through the exterior walls due to destratification fan (Btu/hr)
- \(t_{eff}\) = effective annual operation time, based on balance point temperature (hr)
- \(\eta\) = conversion factor (1 therm = 100,000 Btu)

\[\Delta \text{Therms} = \left[ \text{heat loss reduction through roof due to fan} + \text{heat loss reduction through exterior walls due to fan} \right] \times \text{effective annual operation time (hr)} / 100,000 \times \eta\]

\[= \text{heat loss reduction through roof due to fan} \times \text{number of fans} \times \text{effective annual operation time (hr)} / 100,000 \times \eta\]

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>45°F</th>
<th>50°F</th>
<th>55°F</th>
<th>60°F</th>
<th>65°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>3810</td>
<td>4226</td>
<td>4880</td>
<td>5571</td>
<td>6436</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>3593</td>
<td>3986</td>
<td>4603</td>
<td>5254</td>
<td>6070</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>3038</td>
<td>3370</td>
<td>3891</td>
<td>4442</td>
<td>5131</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>2243</td>
<td>2488</td>
<td>2873</td>
<td>3280</td>
<td>3789</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>2271</td>
<td>2519</td>
<td>2909</td>
<td>3320</td>
<td>3836</td>
</tr>
</tbody>
</table>

100,000 = conversion factor (1 therm = 100,000 Btu)

---

544 These were calculated at various base temperatures using TMY3 data and adjusted to make consistent with the 30 year normal data used elsewhere. For more information see ‘Destratification Fan Workpaper’; Robert Irmiger, Gas Technology Institute, 9/6/2015.
η = thermal efficiency of heating equipment
= Actual. If unknown assume 0.8.

**EXAMPLE:**

For a warehouse facility located in Rockford, IL, installing destratification fans could reduce heat loss through the roof of 95,000 Btu/hr and a reduced heat loss through the wall of 51,228 Btu/hr. Assuming a balance point of 55°F the therms savings for the facility would be estimated as:

\[
\Delta \text{Therms} = \frac{[(\Delta Q_r + \Delta Q_w) \times t_{eff}] / (100,000 \times \eta)}{
\frac{[(95,000 \text{ Btu/hr} + 51,282 \text{ Btu/hr}) \times 4880 \text{ hr}]}{(100,000 \text{ Btu/therm} \times 0.8)}
\]

\[
= 8,923 \text{ therms}
\]

**Heat loss reduction through the roof**

\[
\Delta Q_r = Q_{r,s} - Q_{r,d}
\]

\[
= \left(\frac{1}{R_r}\right) \times A_r \times [(T_{r,s} - T_{oa}) - (T_{r,d} - T_{oa})]
\]

\[
= \left(\frac{1}{R_r}\right) \times A_r \times (T_{r,s} - T_{r,d})
\]

Where:

\( Q_{r,s} \) = roof heat loss for stratified space

\( Q_{r,d} \) = roof heat loss for destratified space

\( R_r \) = overall thermal resistance through the roof (hr * ft² * °F / Btu)

= Actual or estimated based on construction type. If unknown, assume the following:

<table>
<thead>
<tr>
<th>Thermal Resistance Factor (R-Factor) for Roof</th>
<th>Retrofit⁵⁴⁵</th>
<th>New Construction⁵⁴⁶ (2010 or newer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_r )</td>
<td>10.0</td>
<td>20.0</td>
</tr>
<tr>
<td>(hr * ft² * °F / Btu)</td>
<td></td>
<td>(hr * ft² * °F / Btu)</td>
</tr>
</tbody>
</table>

\( A_r \) = roof area (ft²)

= user input

= can be approximated with floor area

\( T_{oa} \) = outside air temperature, note: therm savings calculations are actually independent of outside air because this term drops out of the heat loss reduction equation

\( T_{r,s} \) = indoor temperature at roof deck, stratified case (°F)

= Actual. If unknown, use the following equation

⁵⁴⁵ ANSI/ASHRAE/IESNA 100-1995, “Energy Conservation in Existing Buildings,” ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used.

= m_s * h_r + T_{f,s} \\
h_r = ceiling height/roof deck (ft) \\
m_s = estimated heat gain per foot elevation, stratified case (°F/ft) \\
= 0.8 °F/ft \\

= Professional judgement used to define value based on result from a Nicor Gas ETP Pilot field testing results and the Ansley article. Estimates from these sources fall on the conservative side of the industry rule of thumb range of 1-2 °F/ft heat gain.

T_{f,s} = estimated floor temperature, stratified case (°F) \\
= T_{tstat} - m_s * h_{stat} \\
= T_{tstat} - 4 °F \\

T_{tstat} = temperature set point at the thermostat \\
h_{stat} = vertical distance between the floor and the thermostat, assumed 5ft \\

T_{r,d} = indoor temp at roof, destratified case \\
= actual value, or may be estimated using the following. \\
= T_{tstat} + 1 °F \\

EXAMPLE: 

For a 50,000 ft² warehouse built in 1997 with 30 ft ceilings and a thermostat set point of 65 °F. No further measured values available.

\[
\Delta Q_w = (1/R_w) * A_w * (T_{w,s} - T_{w,d}) = (1/R_w) * A_w * [(m_s * h_r + T_{tstat} - 4 °F) - (T_{tstat} + 1 °F)] \\
= (1/R_w) * A_w * [(0.8 °F/ft * h_r) - 5 °F] \\
= 1/(10 hr * ft² * °F / Btu) * (50,000 ft²) * [(0.8 °F/ft * 30 ft) - 5 °F] \\
= 95,000 Btu/hr \\
\]

Heat loss reduction through exterior walls

Note: a conservative estimate for therms savings would neglect the impact of heat loss through the walls. However, Ansley suggests that estimates based on the roof deck losses alone underestimate actual savings by up to 46%. 

\[
\Delta Q_{w} = Q_{w,s} - Q_{w,d} \\
\Delta Q_{w} = (1/R_w) * A_w * (T_{w,s} - T_{w,d}) \\
\]

Where:


\( R_w = \text{overall thermal resistance through the exterior walls (hr } * \text{ ft}^2 * ^\circ \text{F} / \text{Btu}) \)

\( = \text{Actual or estimated based on construction type}^{552}. \text{If unknown, assume the following} \)

<table>
<thead>
<tr>
<th>Thermal Resistance Factor (R-Factor) for Wall</th>
<th>Retrofit(^{553})</th>
<th>New Construction(^{554}) (2010 or newer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_w )</td>
<td>6.5 (hr } * \text{ ft}^2 * ^\circ \text{F} / \text{Btu})</td>
<td>13.0 (hr } * \text{ ft}^2 * ^\circ \text{F} / \text{Btu})</td>
</tr>
</tbody>
</table>

\( A_w = \text{area of exterior walls (ft}^2) \)

\( = \text{user input} \)

\( T_{w,s} = \text{average indoor air temperature for wall heat loss, stratified case} \)

\( = \text{If actual } T_{r,s} \text{ measurement is available}^{555} \)

\( = \frac{[(T_{r,s} * h_a) + (T_{tstat} * h_b)]}{h_r} \)

\( h_a = \text{vertical distance between the heat source and the ceiling} \)

\( h_b = \text{vertical distance between the floor and the heat source} \)

\( = \text{Otherwise, use the linear stratification equation at average space height, see definition above.} \)

\( = m_s * (h_r / 2) + T_{r,s} \)

\( = m_s * (h_r / 2) + (T_{tstat} - 4) \)

\( T_{w,d} = \text{average indoor air temperature for wall heat loss, destratified case} \)

\( = T_{tstat} + 0.5 \)

---

\(^{552}\) Because heat loss through the walls is estimated using the average space temperature pre- and post- destratification. There are a number of factors that can impact the average space temperature causing deviations from estimates of many degrees in some cases. As such, it is recommended that a conservative value for the thermal resistance through the walls, \( R_w \), be used. A recommended method for determining \( R_w \) would be to use the highest \( R \)-value for the wall space, neglecting lower \( R \)-values associated with windows, thermal bridges, etc.

\(^{553}\) ANSI/ASHRAE/IESNA 100-1995, “Energy Conservation in Existing Buildings,” ASHRAE Standard (1995). Additionally, professional judgement was used to address older vintage structure prior to adoption of the 1995 standard and an estimate of 50% of current code standard was used.


= conservative estimate using engineering judgment based on the same assumption used for \(T_{r,f}\) estimate.

EXAMPLE:
For a 50,000 ft\(^2\) warehouse built in 1997 with 1200 ft length of perimeter wall and 30 ft ceilings and a thermostat set point of 65 °F and a measured temperature at the ceiling of 85 °F and unit heaters located 10 feet from the roof:

\[
\Delta Q_w = (1/R_w) * A_w * (T_{w,s} - T_{w,d})
\]

\[
= (1/R_w) * A_w * \left( \frac{[([T_{r,s} * h_a] + [T_{tstat} * h_b]) / h_i] - (T_{tstat} + 0.5 \, ^\circ F)}{1/(6.5 \, \text{hr}^{2}\text{°F}/\text{Btu}) * (36,000 \text{ft}^2) * (71.7 \, ^\circ F - 65.5 \, ^\circ F)} \right)
\]

\[
= 34,338 \, \text{Btu/hr}
\]

Measure eligibility check
Use the following algorithm to verify a fan system is sufficiently sized to destratify air across the entire area.

Effective area, \(A_{eff}\), is the area over which a fan or a group of fans can be expected to effectively destratify a space. If \(A_{eff}\) is less than the roof area, \(A_r\), a custom analysis approach should be followed to account for the change in the effectiveness of the system. In lieu of more detailed studies, effective area is defined based on the measured results from an Enbridge Gas field study in which the area a fan was expected to effectively destratify was equal to 5 times the fan diameter\(^{556}\). Effective area, is calculated as follows:

\[
A_{eff} = \frac{\pi * (5*D_{fan})^2}{4} * N_{fan}
\]

Where:
- \(A_{eff}\) = the effective area fan area on the floor (ft\(^2\))
- \(D_{fan}\) = fan diameter
- \(N_{fan}\) = the number of fans

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-HVC-DSFN-V02-180101

REVIEW DEADLINE: 1/1/2021

4.4.35 Economizer Repair and Optimization

DESCRIPTION

Economizers are designed to use unconditioned outside air (OSA) instead of mechanical cooling to provide cooling when exterior conditions permit. When the OSA temperature is less than the changeover temperature (determined by a static setpoint or a reference return air sensor) up to 100% OSA is supplied to help meet the facility’s cooling needs, thus reducing mechanical cooling energy and saving energy. An economizer that is not working or is not properly adjusted can waste energy and cause comfort issues. This HVAC Economizer Optimization measure involves the repair and optimization of common economizer problems such as adjusting changeover setpoint, repairing damper motors & linkages and replacing non-working sensors and/or controllers. These repairs and adjustments result in proper operation which maximizes both occupant comfort and energy savings.

This measure is only appropriate for single zone packaged rooftop units. Custom calculations are required for savings for multi-zone systems.

In general the HVAC Economizer Optimization measure may involve both repair and/or optimization;

Economizer Repair – The Economizer repair work is preformed to ensure that the existing economizer is working properly. This allows the system to take advantage of free cooling and ensure that the system is not supplying an excess amount of outside air (OSA) during non-economizing periods.

- Replace Damper Motor – If the existing damper motor is not operational, the unit will be replaced with a functioning motor to allow proper damper modulation.
- Repair Damper linkage – If the existing linkage is broken or not adjusted properly, the unit will be replaced or adjusted to allow proper damper modulation.
- Repair Economizer Wiring – If the existing economizer is not operational due to a wiring issue, the issue will be repaired to allow proper economizer operation.
- Reduce Over Ventilation – If the unit is supplying excess OSA, the OSA damper position will be adjusted to meet minimum ventilation requirements.
- Economizer Sensor Replacement – If the unit is equipped with a nonadjustable dry bulb (i.e. snapdisk) or malfunctioning analog sensor, the sensor is replaced with a new selectable sensor.
- Economizer Control Replacement – If the existing economizer controller is not operational, the unit will be replaced or upgraded to allow for proper economizer operation.

Economizer Optimization - The economizer optimization work is preformed to ensure that the existing economizer system is set up properly to maximize use of free cooling for units located in a particular climate zone.

- Economizer Changeover Setpoint Adjustment – If the unit is equipped with a fully operational economizer, the controller is adjusted to the appropriate changeover setpoint based on ASHRAE 90.1 (Figure 1 - Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers) for the corresponding climate zone.
- Enable Integrated Operation – If the unit is equipped with a fully operational economizer and is not set up to allow a minimum of two stages of cooling (1st stage – Economizer Only & 2nd Stage – Economizer & Mechanical cooling), the unit will be wired to allow two stage cooling.

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment condition is defined by fully functional economizer that is programmed to meet ASHRAE 90.1 economizer changeover setpoint requirements for the facility’s climate zone and changeover control type (Figure 1 - Table 6.5.1.1.3 High-Limit Shutoff Control Settings for Air Economizers)557.

DEFINITION OF BASELINE EQUIPMENT

The baseline for this measure is an existing economizer installed on a packaged single zone rooftop HVAC unit. The existing economizer system is currently not operating as designed due to mechanical and/or control problems, and/or is not optimally adjusted.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 5 years\textsuperscript{558}.

DEEMED MEASURE COST

The cost for this measure can vary considerably depending upon the existing condition of the economizer and the work required to achieve the required efficiency levels. Measure cost should be determined on a site-specific basis.

\textsuperscript{558} California Public Utilities Commission, DEER 2014 EUL Table D08 v2.05
LOADSHAPE

Loadshape C03 - Commercial Cooling

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF ENERGY SAVINGS

The savings calculation methodology uses a regression equation to calculate the energy savings for a variety of common situations. The equation variables are limited to the ranges listed; if the actual conditions fall outside of these ranges custom calculations are required.

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \left( \text{Baseline Energy Use (kWh/Ton)} - \text{Proposed Energy Use (kWh/Ton)} \right) \times \text{Cooling Capacity (Tons)} \]

The following equations are used to calculate baseline and proposed electric energy use.

Electric Energy Use Equations (kWh / ton)

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Changeover Type</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Fixed Dry-Bulb (DB)</td>
<td>cz+CSP*-2.021+EL*-16.362+OAn<em>1.665+OAx</em>-3.13</td>
</tr>
<tr>
<td></td>
<td>Dual Temperature Dry-Bulb (DTDB)</td>
<td>cz+EL*-11.5+OAn<em>1.635+OAx</em>-2.817</td>
</tr>
<tr>
<td></td>
<td>Dual Temperature Enthalpy (DTEnth)</td>
<td>cz+EL*-17.772+OAn<em>1.853+OAx</em>-3.044</td>
</tr>
<tr>
<td></td>
<td>Fixed Enthalpy (Enth)</td>
<td>cz+CSP*-5.228+EL*-17.475+OAn<em>1.765+OAx</em>-3.003</td>
</tr>
<tr>
<td></td>
<td>Analog ABCD Economizers (ABCD)</td>
<td>cz+CSP*-2.234+EL*-16.394+OAn<em>1.744+OAx</em>-3.01</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>DB</td>
<td>cz+CSP*-3.982+EL*-27.508+OAn<em>2.486+OAx</em>-4.684</td>
</tr>
<tr>
<td></td>
<td>DTDB</td>
<td>cz+EL*-20.798+OAn<em>2.365+OAx</em>-3.773</td>
</tr>
<tr>
<td></td>
<td>DTEnth</td>
<td>cz+EL*-30.655+OAn<em>2.938+OAx</em>-4.461</td>
</tr>
<tr>
<td></td>
<td>Enth</td>
<td>cz+CSP*-8.648+EL*-25.678+OAn<em>2.092+OAx</em>-3.754</td>
</tr>
<tr>
<td></td>
<td>ABCD</td>
<td>cz+CSP*-3.64+EL*-24.927+OAn<em>2.09+OAx</em>-3.788</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>DB</td>
<td>cz+CSP*-0.967+EL*-6.327+OAn<em>2.87+OAx</em>-1.047</td>
</tr>
<tr>
<td></td>
<td>DTDB</td>
<td>cz+OAn<em>2.968+OAx</em>-0.943</td>
</tr>
<tr>
<td></td>
<td>DTEnth</td>
<td>cz+EL*-9.799+OAn<em>3.106+OAx</em>-1.085</td>
</tr>
<tr>
<td></td>
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For more information on methodology, please refer to workpaper submitted by CLEAResult titled “CLEAResult_Economizer Repair_151020_Finalv2.doc”. Note that the original ComEd eQuest models were used in the analysis, rather than the VEIC developed models used elsewhere. VEIC do not consider this a significant issue as adjustments from the ComEd models were focused on calibrating EFLH values, not to overall energy use metrics. We also believe using the ComEd models is likely more conservative. It may be appropriate to update the analysis with the updated models at a later time.

This approach allows the savings estimate to account for the operational attributes of the baseline as well as the proposed case, yielding a better estimate than an approach that assumes a particular baseline or proposed energy use to determine savings.
### Building Type Changeover Type Equation

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Changeover Type</th>
<th>Equation</th>
</tr>
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<tr>
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Where:

- **CZ** = Climate Zone Coefficient
- **CZ1** = Depends on Building Type and Changeover Type (see table below)

### Electric Climate Zone Coefficients

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<tr>
<th>Building Type</th>
<th>Changeover Type</th>
<th>CZ1 (Rockford)</th>
<th>CZ2 (Chicago)</th>
<th>CZ3 (Springfield)</th>
<th>CZ4 (Belleville)</th>
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### Electric Climate Zone Coefficients

<table>
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<tr>
<th>Building Type</th>
<th>Changeover Type</th>
<th>CZ1 (Rockford)</th>
<th>CZ2 (Chicago)</th>
<th>CZ3 (Springfield)</th>
<th>CZ4 (Belleville)</th>
<th>CZ5 (Marion)</th>
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**CSP** = Economizer Changeover Setpoint (°F or Btu/lb) (actual in ranges below)

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<tr>
<th>Economizer Control Type</th>
<th>Economizer Changeover Setpoint</th>
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<tr>
<td>Dry-Bulb</td>
<td>60°F - 80°F</td>
</tr>
<tr>
<td>Dual Temperature Dry-Bulb</td>
<td>0°F - 5°F</td>
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<tr>
<td>Dual Temperature Enthalpy</td>
<td>0 Btu/lb - 5 Btu/lb delta</td>
</tr>
<tr>
<td>Enthalpy</td>
<td>18 Btu/lb - 28 Btu/lb</td>
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</table>

**EL** = Integrated Economizer Operation (Economizer Lockout)

- 0 for Economizer w/ Integrated Operation (Two Stage Cooling)
- 1 for Economizer w/ out Integrated Operation (One Stage Cooling)

**Oan** = Minimum Outside Air (% OSA)

- Actual. Must be between 15% -70%. If unknown assume
  - Functional Economizer – 30%
  - Non functional Economizer (Damper failed closed) – 15%
  - Non functional Economizer (Damper failed open) - 30% (Assume Minimum Ventilation (Three Fingers))

**Oax** = Maximum Outside Air (%)

- Actual. Must be between 15% -70%. If unknown assume
  - Functional Economizer – 70%
  - Non functional Economizer (Damper failed closed) – 15%

---


Non functional Economizer (Damper failed open) — 30% (Assume Minimum Ventilation (Three Fingers))

**EXAMPLE**

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programmed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found that the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

\[ \Delta \text{kWh} = (\text{Baseline Energy Use (kWh/Ton)} - \text{Proposed Energy Use (kWh/Ton)}) \times \text{Cooling Capacity (Tons)} \]

Baseline Energy Use (kWh/Ton) = Equation for Office Low Rise
\[
= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047
= 674.06+62*-0.967+0*-6.327+30*2.87+30*-1.047
= 668.8 \text{ kWh/Ton}
\]

Proposed Energy Use (kWh/Ton) = Equation for Office Low Rise
\[
= cz+CSP*-0.967+EL*-6.327+OAn*2.87+OAx*-1.047
= 674.06+70*-0.967+0*-6.327+ 30*2.87+70*-1.047
= 619.2 \text{ kWh/Ton}
\]

\[ \Delta \text{kWh} = (668.8 \text{ (kWh/Ton)} - 619.2 \text{ (kWh/Ton)}) \times 5 \text{ Tons} \]
\[
= 49.6 \text{ kWh/Ton} \times 5 \text{ Tons}
= 248.08 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A - It is assumed that repair or optimization of the economizer will not typically have a significant impact summer peak demand.

**NATURAL GAS SAVINGS**

\[ \Delta \text{Therms} = (\text{Baseline Energy Use (Therms/kBtuh)} - \text{Proposed Energy Use (Therms/kBtuh)}) \times \text{Output Heating Capacity (kBtuh)} \]

The following equations are used to calculate baseline and proposed electric energy use.

**Natural Gas Energy Use Equations (therms / kbtu output)**

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Changeover Type</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
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<td>Analog ABCD Economizers (ABCD)</td>
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### Building Type Changeover Type Equation

<table>
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<th>Building Type</th>
<th>Changeover Type</th>
<th>Equation</th>
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<tr>
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Where:

- \(CZ\) = Climate Zone Coefficient
- Depends on Building Type and Changeover Type (see table below)

### Natural Gas Climate Zone Coefficients

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<thead>
<tr>
<th>Building Type</th>
<th>Changeover Type</th>
<th>CZ1 (Rockford)</th>
<th>CZ2 (Chicago)</th>
<th>CZ3 (Springfield)</th>
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## Natural Gas Climate Zone Coefficients

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</table>
EXAMPLE

A low rise office building in Rockford (Climate Zone 1) is heated and cooled with a packaged Gas (92 kBtu output) / DX (5 Ton) RTU. The RTU is equipped with a fixed dry-bulb outside air economizer and is programmed for integrated operation. When the technician inspects the RTU they find that the changeover setpoint is programmed to 62°F, which does not meet ASHRAE economizer high limit shut off air economizer recommendations. After further investigation it is found the OSA damper motor is not operational and is providing 30% outside air.

The technician replaces the damper motor and allow for proper OSA damper modulation (30% Min OSA & 70% Max OSA). They also adjust the fixed dry-bulb changeover setpoint to meet the ASHRAE economizer high limit shut off air economizer recommendation of 70°F.

\[
\Delta \text{Therms} = \left[ \text{Baseline Energy Use (Therms/kBtuh)} - \text{Proposed Energy Use (Therms/kBtuh)} \right] \times \text{Output Heating Capacity (kBtuh)}
\]

Baseline Energy Use (Therms/kBtuh) = Equation for Office Low Rise

\[= \text{cz+OAn*0.3} \]
\[= 5.83 + 30 \times 0.3 \]
\[= 14.8 \text{ Therms/kBtuh output} \]

Proposed Energy Use (Therms/kBtuh) = Equation for Office Low Rise

\[= \text{cz+OAn*0.3} \]
\[= 5.83 + 30 \times 0.3 \]
\[= 14.8 \text{ Therms/kBtuh output} \]

\[
\Delta \text{Therms} = \left[ 14.8 \text{(Therms/kBtuh output)} - 14.8 \text{ (Therms/kBtuh output)} \right] \times 92\text{kBtuh output}
\]
\[= 0.0 \text{ (Therms/kBtuh output)} \times 92\text{kBtuh output} \]
\[= 0 \text{ Therms} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-HVC-ECRP-V02-160601

REVIEW DEADLINE: 1/1/2023
4.4.36 Multi-Family Space Heating Steam Boiler Averaging Controls

**DESCRIPTION**

This measure covers multi-family space heating boiler averaging controls. Temperature sensors are placed in interior spaces to monitor the average temperature of the building. At minimum a sensor must be placed at each corner and at one central location. Additionally, a temperature sensor must monitor the outside air temperature. These sensors shall provide data to the averaging controls. The averaging controls will adjust the boiler operation based upon an average of the indoor sensors and the outside air temperature. These controls shall also incorporate a night-time setback capability. Buildings utilizing thermostatic radiator valves, or other modulating control valves or sequences to control the temperature in individual spaces are not eligible.

This measure was developed to be applicable to the following program types: RF.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify the boiler(s) must incorporate an averaging control system utilizing at least 5 indoor sensors and 1 outdoor sensor. The controls shall have the capability to incorporate a nighttime setback throughout the building.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is a boiler system without averaging controls or other steam supply modulating controls. Current boiler control system can utilize a single thermostat or aquastat and timer.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the domestic hot water boilers is 20 years.\(^{563}\)

**DEEMED MEASURE COST**

**AS A RETROFIT MEASURE, THE ACTUAL INSTALLED COST SHOULD BE USED FOR SCREENING PURPOSES.**

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

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**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

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**Natural Gas Energy Savings**

\[ \Delta \text{Therms} = \text{Capacity} \times \text{EFLH} \times \text{SF} / 100,000 \]

Where:

- **Capacity** = Boiler gas input size (Btu/h)
- **EFLH** = Effective Full Load Hours for heating are provided in section 4.4. HVAC End Use
- **SF** = Savings Factor
  - $5\%^{564}$ or custom if savings can be substantiated
- **100,000** = converts Btu/h to therm

For Example:

A 1,000,000 btu/h steam boiler in a Mid-Rise Multi-Family building in Chicago has averaging controls installed.

\[ \Delta \text{Therms} = 1,000,000 \times 1,685 \times 0.05 / 100,000 \]
\[ = 843 \text{ therms} \]

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code: CI-HVC-SBAC-V01-160601**

**Review Deadline: 1/1/2022**

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$^{564}$ A conservative estimate considering only setback savings, with DOE estimates as much as 1% per degree per 8 hours of setback.  
[http://energy.gov/energysaver/thermostats](http://energy.gov/energysaver/thermostats)
4.4.37 Unitary HVAC Condensing Furnace

DESCRIPTION

Condensing furnaces recover energy in combustion exhaust flue gasses that would otherwise simply be vented to the atmosphere, making them more efficient than non-condensing furnaces. This measure applies to a constant volume (CV), dedicated outside air system (DOAS), make-up air system (MUAS), or any unitary HVAC system that is utilizing an indirect gas fired process to heat 100% OA to provide ventilation or make-up air to commercial and industrial (C&I) building spaces. The unitary package must contain an indirect gas-fired, warm air furnace section, but the unitary package can be with or without an electric air conditioning section. The unitary package can be either a single package or split system that is applied indoors (non-weathered) or outdoors (weatherized).

This measure excludes demand control ventilation, condensing unit heaters, and high efficiency (condensing) furnaces with annual fuel utilization efficiency (AFUE) ratings (for furnaces with less than 225,000 Btu/hr input capacity), which are covered by other measures for the C&I sector in the Technical Reference Manual (TRM)\(^{566}\).

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure, the efficient unitary equipment must contain a condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 90% or higher, or alternatively, the unitary package must have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.90 or higher. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces.\(^{566}\) The furnace must be vented and condensate disposed of in accordance with the equipment manufacturer installation instructions and applicable codes.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is expected to be unitary equipment that contains a non-condensing, warm air furnace with a natural gas thermal efficiency (TE) rating of 80%, or alternatively, the unitary package will have equipment nameplate information for natural gas that identifies a heating output and heating input rating that has an output over input ratio of 0.80. These ratings must be certified by a recognized testing laboratory in accordance with American National Standards Institute (ANSI) Standard Z21.47 for Gas-Fired Central Furnaces.

Note the current Department of Energy (DOE) federal minimum efficiency standard is 80% for 225,000 Btu/hr and higher input capacity furnaces per the Energy Conservation Standard for Commercial Warm Air Furnaces\(^{567}\). In the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings\(^{568}\) that minimum TE requirement is extended below 225,000 Btu/hr input capacity to require all commercial warm air furnaces and combination warm air furnace/air conditioning units to meet the minimum 80% TE.


DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years, which is consistent with the established TRM measure life for single-package and split system unitary air conditioners, since in colder climates these unitary packages typically contain a gas-fired, warm air furnace section, with an electric air conditioning section.

DEEMED MEASURE COST

The actual incremental equipment and installation costs should be used, if available. If not, the incremental cost of $5.42 per 1000 Btu/hr of output capacity should be used for the condensing furnace equipment (as part of a unitary package) and its installation (including the combustion condensate drainage and disposal system). This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard\(^569\). Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.

LOADSHAPE

Loadshape C23 - Commercial Ventilation

COINCIDENCE FACTOR

The coincidence factor is assumed to be 1.0 – that is, building ventilation will always be provided during peak periods.

Algorithm

CALCULATION OF SAVINGS

The following methodology provides formulas for estimating gas heating savings associated with condensing furnaces in unitary HVAC packages when applied as a CV, DOAS, MUAS, or any RTU that is indirectly heating 100% outside air (OA). These types of HVAC systems typically run continuously during the HVAC operating schedule to provide building ventilation and maintain indoor air quality or to compensate for exhaust and maintain neutral or slightly positive building pressurization. The algorithm estimates the gas use reduction resulting from utilizing condensing heating of 90% or higher thermal efficiency (TE) in place of the federal minimum TE of 80% (or other user defined baseline TE) for commercial warm air furnaces.

The methodology provides a representative group of operating schedules for the market sector applications highlighted earlier based on DOE commercial reference building models\(^570\). Heating loads during the operating schedule are determined based on hourly differences between a range of supply air (SA) heated to temperatures and the OA temperature using Typical Meteorological Year (TMY3)\(^571\) weather data. These hourly heating loads are generated for all hours when the OA temperature is below the base temperature of 55 °F for heating in C&I settings per the TRM. To accommodate the variability in heating base temperatures in C&I settings, these hourly heating loads are also generated for base temperatures of 45 °F and 65 °F for heating. The hourly heating loads are then summed for the entire year. The annual heating loads are calculated in this manner for the climate zone 2 weather station (Chicago O’Hare Airport), which is then normalized to its National Climatic Data Center (NCDC)\(^572\) 30 year (1981-2010) weather average by multiplying by the heating degree day (HDD) ratio of the NCDC/TRM HDD55 over the TMY3 HDD55 (HDD at base temperature of 55 °F), and likewise for the annual heating loads for HDD45 (HDD at

---


base temperature of 45 °F) and HDD65 (HDD at base temperature of 65 °F), using the values in Table 1 and Table 2. Since detailed hourly weather data is not available for all 5 of the TRM climate zone weather stations, the annual heating loads for the other climate zones are determined by multiplying the climate zone 2 annual heating loads by the ratio of the other climate zone NCDC HDD over the climate zone 2 NCDC HDD, using the values in Table 1.

These annual heating loads on a per unit airflow basis are then used in conjunction with the actual airflow of the 100% OA system and its condensing efficiency to calculate the gas heating savings versus the baseline (non-condensing) heating efficiency. This measure results in additional electric use by the unitary HVAC package due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

**Table 1. NCDC/TRM HDD Values for All Climate Zones**

<table>
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<th>Climate Zone - Weather Station/City</th>
<th>NCDC 30 Year Average HDD45°F</th>
<th>NCDC 30 Year Average HDD55°F</th>
<th>NCDC 30 Year Average HDD65°F</th>
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<td>2495</td>
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<td>3406</td>
<td>5495</td>
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<td>4 - Belleville SIU RSCH / Belleville</td>
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<td>2515</td>
<td>4379</td>
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<td>5 - Carbondale Southern IL AP / Marion</td>
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**Table 2. TMY3 HDD Values for Climate Zone 2**

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<th>Climate Zone - Weather Station/City</th>
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**Electric Energy Savings**

As noted previously, this measure results in additional SA fan electric use by the unitary HVAC system due to the additional pressure drop of the condensing heat exchanger of the warm air furnace section.

\[
\Delta \text{kWh} = -(t_{\text{FAN}} \times \text{cfm} \times \Delta P) / (\eta_{\text{FAN/MOTOR}} \times 8520)
\]

Where:

- \(t_{\text{FAN}}\) = annual fan runtime (hr), refer to Tables 1 through 4
- \(\text{cfm}\) = airflow (cfm), use actual or rated system airflow
- \(\Delta P\) = incremental pressure drop (inch W.G.), assume 0.15 if actual value not known
- \(\eta_{\text{FAN/MOTOR}}\) = combined fan and motor efficiency, assume 0.60 if actual value not known
8520 = conversion factor (fan horsepower – HP – calculation constant of 6356 for standard air conditions adjusted by 1 HP = 0.746 kW, or 6356/0.746 = 8520 for this kW calculation)

**EXAMPLE:**

For a “big box” retail store operating 24 hours a day and 7 days a week (8760 hours per year) with a 5000 cfm DOAS that has an incremental pressure drop of 0.15 inch W.G. and a combined fan and motor efficiency of 0.6 has annual kWh savings of:

\[
\Delta kW = \frac{(t_{\text{fan}} \times \text{cfm} \times \Delta P)}{t_{\text{fan/motor}} \times 8520}
\]

\[
= \frac{(8760 \times 5000 \times 0.15)}{(0.6 \times 8520)}
\]

\[
= -1285 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

The additional SA fan electric use by the unitary HVAC system will typically result in a modest electric demand increase.

\[
\Delta kW = \frac{(\Delta kW / t_{\text{fan}})}{\text{CF}}
\]

Where:

CF = 1.0

**EXAMPLE:**

Continuing the previous example:

\[
\Delta kW = \frac{(\Delta kW / t_{\text{fan}})}{\text{CF}}
\]

\[
= (-1285 / 8760) \times 1.0
\]

\[
= -0.15 \text{ kW}
\]

**NATURAL GAS ENERGY SAVINGS**

\[
\Delta\text{Therms} = \frac{[Q_{OA} \times \text{cfm} \times (1/TE_{NC} - 1/TE_{C})]}{100,000}
\]

Where:

\[
Q_{OA} = \text{annual outside air (OA) heating load per cfm of OA (Btu/cfm)}
\]

First, select the most representative operating schedule for the application from among the four (4) scenarios listed below and its set of three (3) applicable tables. Second, select the table in that set with the most representative HDD base temperature – the base temperature for OA below which heating is required. If that base temperature is not readily determined, select the TRM default base temperature of 55 °F (HDD55) for heating in C&I settings. Third, select the climate zone within that table. Fourth, select an appropriate heated to supply air (SA) temperature within that table. Use the resulting Q_{OA} value, with linear interpolation allowed between SA temperatures.
The four (4) scenarios available are indicative of the following building applications and operating schedules:

1. 24 hour a day and 7 day a week (24/7) operation, with HVAC operating schedule of 8760 hours per year, typical of large retail stores with DOAS, hotel/multifamily buildings with corridor MUAS, and healthcare facilities with DOAS. Use Table 3 through Table 5.

2. 6:00 AM to 1:00 AM every day operation, with HVAC operating schedule of 7300 hours per year, typical of full service and quick service restaurants with kitchen MUAS. Use Table 6 through Table 8.

3. 7:00 AM to 9:00 PM Monday-Friday, 7:00 AM to 10:00 PM Saturday, and 9:00 AM to 7:00 PM Sunday operations, with HVAC operating schedule of 5266 hours per year, typical of non-24/7 retail stores with DOAS. Use Table 9 through Table 11.

4. 7:00 AM to 9:00 PM Monday-Friday operation, with HVAC operating schedule of 3911 hours per year, typical of school buildings with DOAS. Use Table 12 through Table 14.

where:

- \( T_{\text{ENC}} \) = non-condensing thermal efficiency (TE), use federal minimum TE of 80% (0.80) or actual TE if known
- \( T_{\text{EC}} \) = condensing thermal efficiency (TE), use actual TE or if unknown assume 90% (0.90)
- 100,000 = conversion factor (1 therm = 100,000 Btu)

**EXAMPLE:**

Continuing the previous example, for a climate zone 2 (Chicago O’Hare AP / Chicago) application using a 90% TE condensing DOAS with a supply air temperature from the DOAS of 95 °F:

\[
\Delta\text{Therms} = \frac{Q_{\text{OA}} \times \text{cfm} \times (1/T_{\text{ENC}} - 1/T_{\text{EC}})}{100,000}
\]

\[
= 303,268 \times 5,000 \times (1/0.80 - 1/0.90)/100,000
\]

\[
= 2,106 \text{ therms}
\]

### 8760 Hour Annual Operation Scenario

**Table 3. 8760 Hour Annual Operation Scenario for HDD45**

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>Supply Air Fan Runtime = 8760 Hours</th>
<th>( Q_{\text{OA}} ) (Annual Btu/cfm) At Supply Air Temperature Of</th>
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<tr>
<td></td>
<td>75°F</td>
<td>85°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>189,343</td>
<td>230,897</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>171,737</td>
<td>209,427</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>137,511</td>
<td>167,689</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>90,839</td>
<td>110,775</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>89,777</td>
<td>109,479</td>
</tr>
</tbody>
</table>
### Table 4. 8760 Hour Annual Operation Scenario for HDD55

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>216,145</td>
<td>268,852</td>
<td>321,559</td>
<td>374,266</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>203,850</td>
<td>253,559</td>
<td>303,268</td>
<td>352,977</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>172,329</td>
<td>214,351</td>
<td>256,374</td>
<td>298,397</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>127,248</td>
<td>158,278</td>
<td>189,307</td>
<td>220,337</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>128,817</td>
<td>160,229</td>
<td>191,641</td>
<td>223,053</td>
</tr>
</tbody>
</table>

### Table 5. 8760 Hour Annual Operation Scenario for HDD65

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>239,158</td>
<td>308,050</td>
<td>376,942</td>
<td>445,834</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>230,820</td>
<td>297,311</td>
<td>363,802</td>
<td>430,292</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>200,056</td>
<td>257,685</td>
<td>315,314</td>
<td>372,943</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>159,426</td>
<td>205,351</td>
<td>251,276</td>
<td>297,200</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>162,994</td>
<td>209,947</td>
<td>256,899</td>
<td>303,852</td>
</tr>
</tbody>
</table>

### 7300 Hour Annual Operation Scenario

### Table 6. 7300 Hour Annual Operation Scenario for HDD45

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>151,914</td>
<td>185,369</td>
<td>218,823</td>
<td>252,278</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>137,788</td>
<td>168,132</td>
<td>198,476</td>
<td>228,819</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>110,328</td>
<td>134,624</td>
<td>158,921</td>
<td>183,217</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>72,882</td>
<td>88,932</td>
<td>104,982</td>
<td>121,033</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>72,030</td>
<td>87,892</td>
<td>103,755</td>
<td>119,617</td>
</tr>
</tbody>
</table>

### Table 7. 7300 Hour Annual Operation Scenario for HDD55

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>173,511</td>
<td>215,950</td>
<td>258,389</td>
<td>300,828</td>
</tr>
<tr>
<td>2 - Chicago O'Hare AP / Chicago</td>
<td>163,641</td>
<td>203,666</td>
<td>243,691</td>
<td>283,716</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>138,338</td>
<td>172,134</td>
<td>206,010</td>
<td>239,846</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>102,149</td>
<td>127,133</td>
<td>152,118</td>
<td>177,103</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>103,408</td>
<td>128,701</td>
<td>153,993</td>
<td>179,286</td>
</tr>
</tbody>
</table>
### Table 8. 7300 Hour Annual Operation Scenario for HDD65

<table>
<thead>
<tr>
<th>Supply Air Fan Runtime = 7300 Hours</th>
<th>$Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Zone - Weather Station/City</td>
<td>75°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>191,803</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>185,117</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>160,444</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>127,859</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>130,720</td>
</tr>
</tbody>
</table>

### 5266 Hour Annual Operation Scenario

### Table 9. 5266 Hour Annual Operation Scenario for HDD45

<table>
<thead>
<tr>
<th>Supply Air Fan Runtime = 5266 Hours</th>
<th>$Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Zone - Weather Station/City</td>
<td>75°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>104,175</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>94,488</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>75,657</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>49,979</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>49,394</td>
</tr>
</tbody>
</table>

### Table 10. 5266 Hour Annual Operation Scenario for HDD55

<table>
<thead>
<tr>
<th>Supply Air Fan Runtime = 5266 Hours</th>
<th>$Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Zone - Weather Station/City</td>
<td>75°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>118,320</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>111,590</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>94,335</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>69,657</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>70,516</td>
</tr>
</tbody>
</table>

### Table 11. 5266 Hour Annual Operation Scenario for HDD65

<table>
<thead>
<tr>
<th>Supply Air Fan Runtime = 5266 Hours</th>
<th>$Q_{oa}$ (Annual Btu/cfm) At Supply Air Temperature Of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate Zone - Weather Station/City</td>
<td>75°F</td>
</tr>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>130,903</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>126,339</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>109,501</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>87,262</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>89,215</td>
</tr>
</tbody>
</table>

### 3911 Hour Annual Operation Scenario
Table 12. 3911 Hour Annual Operation Scenario for HDD45

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>75,029</td>
<td>91,729</td>
<td>108,428</td>
<td>125,128</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>68,053</td>
<td>83,199</td>
<td>98,346</td>
<td>113,492</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>54,490</td>
<td>66,618</td>
<td>78,746</td>
<td>90,874</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>35,996</td>
<td>44,008</td>
<td>52,019</td>
<td>60,031</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>35,575</td>
<td>43,493</td>
<td>51,411</td>
<td>59,329</td>
</tr>
</tbody>
</table>

Table 13. 3911 Hour Annual Operation Scenario for HDD55

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>85,672</td>
<td>106,825</td>
<td>127,979</td>
<td>149,132</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>80,799</td>
<td>100,749</td>
<td>120,699</td>
<td>140,649</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>68,305</td>
<td>85,170</td>
<td>102,035</td>
<td>118,901</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>50,436</td>
<td>62,890</td>
<td>75,343</td>
<td>87,797</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>51,058</td>
<td>63,665</td>
<td>76,272</td>
<td>88,879</td>
</tr>
</tbody>
</table>

Table 14. 3911 Hour Annual Operation Scenario for HDD65

<table>
<thead>
<tr>
<th>Climate Zone - Weather Station/City</th>
<th>75°F</th>
<th>85°F</th>
<th>95°F</th>
<th>105°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Rockford AP / Rockford</td>
<td>95,460</td>
<td>123,294</td>
<td>151,128</td>
<td>178,963</td>
</tr>
<tr>
<td>2 - Chicago O’Hare AP / Chicago</td>
<td>92,132</td>
<td>118,996</td>
<td>145,860</td>
<td>172,724</td>
</tr>
<tr>
<td>3 - Springfield #2 / Springfield</td>
<td>79,853</td>
<td>103,136</td>
<td>126,420</td>
<td>149,703</td>
</tr>
<tr>
<td>4 - Belleville SIU RSCH / Belleville</td>
<td>63,635</td>
<td>82,190</td>
<td>100,745</td>
<td>119,299</td>
</tr>
<tr>
<td>5 - Carbondale Southern IL AP / Marion</td>
<td>65,059</td>
<td>84,029</td>
<td>102,999</td>
<td>121,969</td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The actual incremental annual maintenance costs should be used, if available. If not, the incremental cost of $0.05 per 1000 Btu/hr of output capacity should be used for maintaining the combustion condensate disposal system yearly. This incremental cost is from the DOE Technical Support Document for the Notice of Proposed Rulemaking (NOPR) for the Commercial Warm Air Furnace Standard6. Per the DOE documentation, it is based on their representative 250,000 Btu/hr input capacity furnace at a 92% TE.
MEASURE CODE: CI-HVC-DSFN-V01-160601

REVIEW DEADLINE: 1/1/2019
4.4.38 Covers and Gap Sealers for Room Air Conditioners

DESCRIPTION

Room air conditioners (window ACs, through-the-wall or sleeve ACs, PTACs or PTHPs) constitute a permanent or semi-permanent penetration through the building’s envelope. These units are often poorly installed, resulting in gaps that act like air leakage pathways through the building’s envelope. The uncontrolled movement of air across the gaps in the envelope (infiltration) increases the building’s winter heating requirements and reduces its overall energy performance.

The heat loss and infiltration can be reduced by installing a rigid or flexible insulated cover on the inside of a room AC. These covers should be maintained by building staff and should remain installed through the heating season. Simple uninsulated cloth covers with no sealing at edges do not qualify for this measure.

There are several types of AC covers available that may be eligible for this measure:

1. If the room AC is left in the window or sleeve, a rigid cover that covers the indoor side of the AC unit with foam gaskets to seal the edges may be installed.
2. If the room AC is absent or is removed during the heating months, a rigid cover that fits inside the sleeve with foam gaskets along the edges for proper air sealing may be installed.
3. Flexible covers that are well insulated and perfectly cover the indoor side of the AC unit may also be eligible for this measure.

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

DEFINITION OF EFFICIENT EQUIPMENT

The installed equipment is a rigid cover that fits inside the empty sleeve or completely covers the indoor side of a window AC unit, with foam gaskets sealing the edges. A flexible insulated cover that perfectly covers the indoor side of the unit and seals gaps may also be installed. Covers should remain installed throughout the winter heating season.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a room AC (window AC, through-the-wall or sleeve AC, PTAC or PTHP) that is poorly installed with gaps around the edges and does not use AC covers or gap sealers during the winter heating months.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life of typical AC covers is 5 years.\(^{573}\)

DEEMED MEASURE COST

The measure cost is the full cost of installing AC covers. Actual installation costs (material and labor) should be used if available. In actual costs are unknown, assume material cost\(^{574}\) of $24 (flexible covers) up to $119, depending on size of the AC unit. The install time per unit is 15 to 30 minutes at assumed labor rate of $20/hour.

LOADSHAPE

Loadshape C04 – Commercial Electric Heating

COINCIDENCE FACTOR

N/A


\(^{574}\) Cost estimates from customer invoices and vendors. Material costs can be lower for bulk orders.
Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

If the building is electrically heated, electric energy savings are calculated as follows:

\[
\Delta k\text{Wh} = \left( Q_{\text{infiltration}} \times 1.08 \times (T_{\text{OA}} - T_{\text{SA}}) \times \text{EFLH}_{\text{heat}} \right) / (3,412 \times \text{COP})
\]

Where:

- \( Q_{\text{infiltration}} \) = Air infiltration (CFM) due to poor installation of window or through-the-wall AC

\[
= \text{ELA} \times 0.000645 \times (f_s^2 \times (T_{\text{OA}} - T_{\text{SA}}) + f_w^2 \times U^2)^{1/2} \times 2118.88
\]

Where:

- \( \text{ELA} \) = Effective Leakage Area (sq. in.)
  - Can be collected on site; if unknown, assume 6 sq. in.

- \( 0.000645 \) = Converts square inches to square meters

- \( f_s \) = Stack Coefficient

\[
= 1/3 \times (9.81 \times \text{Height} \times 0.3048) / (T_{\text{OA}})^{0.5}
\]

- \( f_w \) = Wind Coefficient

\[
= A \times B \times (\text{Height} \times 0.3048) / (10)^C
\]

Where:

- \( 9.81 \) = Acceleration due to gravity (m/s\(^2\))

- \( \text{Height} \) = Height of the location of the leakage area in feet

= Assume 8 ft per floor

- \( T_{\text{OA}} \) = Average Outside Air Temperature during heating period

Use values from table below, based on facility location. This figure must be in Kelvin to determine Stack Coefficient \( f_s \) and infiltration \( Q_{\text{infiltration}} \), but in Fahrenheit to determine energy savings \( \Delta k\text{Wh}, \Delta \text{Therm} \).

<table>
<thead>
<tr>
<th>Zone</th>
<th>( T_{\text{OA}} ) (°F)</th>
<th>( T_{\text{OA}} ) (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 (Rockford)</td>
<td>31.63</td>
<td>272.94</td>
</tr>
<tr>
<td>Zone 2 (Chicago)</td>
<td>33.99</td>
<td>274.26</td>
</tr>
<tr>
<td>Zone 3 (Springfield)</td>
<td>34.38</td>
<td>274.58</td>
</tr>
<tr>
<td>Zone 4 (Belleville)</td>
<td>36.24</td>
<td>275.51</td>
</tr>
<tr>
<td>Zone 5 (Marion)</td>
<td>39.07</td>
<td>277.08</td>
</tr>
</tbody>
</table>

---

575 Infiltration equation and values for stack and wind coefficient equations from “The Use of Blower Door Data.” Max Sherman, 1998. The equation is adjusted for wall leakage area (i.e. no ceiling or floor leakage).

576 Average effective leakage area for multi-family building AC units from “There are Holes in Our Walls.” Prepared for Urban Green Council by Steven Winter Associates, April 2011.

577 “Heating Period” is defined as hours when the TMY3 dry bulb temperature is less than 55°F (balance point)

578 Based on NREL’s Typical Meteorological Year 3 (TMY3) data for different weather stations.
A, B and C = Constants based on the facility site’s shielding and terrain parameters. Use values from the tables below.579.

<table>
<thead>
<tr>
<th>Shielding Class</th>
<th>Shielding Type</th>
<th>Shielding Description</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>No obstructions or local shielding whatsoever (i.e. isolated building)</td>
<td>0.324</td>
</tr>
<tr>
<td>2</td>
<td>Light</td>
<td>Light local shielding with few obstructions (e.g. A few trees or a shed in the vicinity)</td>
<td>0.285</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Moderate local shielding; some obstructions within two house heights (e.g. Thick hedge fence on fence and nearby building)</td>
<td>0.24</td>
</tr>
<tr>
<td>4</td>
<td>Heavy</td>
<td>Heavy shielding; obstructions around most of perimeter buildings or trees within five building heights in most directions (e.g. Well developed/dense tract house)</td>
<td>0.185</td>
</tr>
<tr>
<td>5</td>
<td>Very Heavy</td>
<td>Very heavy shielding, large obstruction surrounding perimeter within two house heights (e.g. Typical downtown area)</td>
<td>0.102</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Terrain Class</th>
<th>Terrain Type</th>
<th>Terrain Description</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>None</td>
<td>Ocean or other body of eater with at least 5 km of unrestricted space</td>
<td>1.3</td>
<td>0.1</td>
</tr>
<tr>
<td>2</td>
<td>Light</td>
<td>Flat terrain with some isolated obstacles (e.g. Buildings or trees well separated from each other)</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Rural areas with low buildings, trees etc.</td>
<td>0.85</td>
<td>0.2</td>
</tr>
<tr>
<td>4</td>
<td>Heavy</td>
<td>Urban, industrial or forest areas</td>
<td>0.67</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>Very Heavy</td>
<td>Center of large city (e.g. Manhattan)</td>
<td>0.47</td>
<td>0.35</td>
</tr>
</tbody>
</table>

0.3048 = Converts feet to meters

\(T_{SA}\) = Average Indoor Air Temperature during heating period. This figure will need to be in Kelvin to calculate infiltration \(Q_{\text{infiltration}}\) and Fahrenheit to calculate energy savings \(\Delta kWh, \Delta \text{Therms}\).

= Collected on site. If unknown, assume 72°F (295 K). If known, convert °F to K by using the following equation: \(K = (\text{°F} + 459.67) \times (5/9)\).

\(U\) = Average Wind Velocity (m/s) during heating period. Use table below, based on facility location.580

<table>
<thead>
<tr>
<th>Zone</th>
<th>U (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1 (Rockford)</td>
<td>4.50</td>
</tr>
<tr>
<td>Zone 2 (Chicago)</td>
<td>4.67</td>
</tr>
<tr>
<td>Zone 3 (Springfield)</td>
<td>4.60</td>
</tr>
<tr>
<td>Zone 4 (Belleville)</td>
<td>3.92</td>
</tr>
<tr>
<td>Zone 5 (Marion)</td>
<td>3.07</td>
</tr>
</tbody>
</table>

2118.88 = Converts m³/s to CFM


580 Based on TMY3 data, see “Covers for Room AC_11092016.xls” for more information.
1.08 = Sensible heat transfer constant (Btu/hr.CFM.°F)
EFLH_{heat} = Equivalent Full Load Hours for heating from section 4.4 HVAC End Use^{581}
3,412 = Converts Btus to kWh
COP = Coefficient of Performance of the heating unit
= Collected on site. If unknown assume 2.6 for PTHP^{582}

Deemed per-unit savings for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

<table>
<thead>
<tr>
<th>Floor</th>
<th>Height</th>
<th>Rockford</th>
<th>Chicago</th>
<th>Springfield</th>
<th>Belleville</th>
<th>Marion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>55.18</td>
<td>53.16</td>
<td>45.70</td>
<td>31.09</td>
<td>25.67</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>68.19</td>
<td>65.31</td>
<td>56.17</td>
<td>38.72</td>
<td>32.66</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>77.92</td>
<td>74.34</td>
<td>63.96</td>
<td>44.45</td>
<td>37.97</td>
</tr>
<tr>
<td>4</td>
<td>32</td>
<td>86.04</td>
<td>81.85</td>
<td>70.44</td>
<td>49.25</td>
<td>42.44</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>93.15</td>
<td>88.42</td>
<td>76.11</td>
<td>53.46</td>
<td>46.37</td>
</tr>
<tr>
<td>6</td>
<td>48</td>
<td>99.56</td>
<td>94.34</td>
<td>81.22</td>
<td>57.26</td>
<td>49.93</td>
</tr>
<tr>
<td>7</td>
<td>56</td>
<td>105.44</td>
<td>99.76</td>
<td>85.90</td>
<td>60.75</td>
<td>53.20</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>110.91</td>
<td>104.80</td>
<td>90.25</td>
<td>63.99</td>
<td>56.24</td>
</tr>
<tr>
<td>9</td>
<td>72</td>
<td>116.04</td>
<td>109.53</td>
<td>94.33</td>
<td>67.04</td>
<td>59.11</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>120.89</td>
<td>114.00</td>
<td>98.19</td>
<td>69.92</td>
<td>61.81</td>
</tr>
<tr>
<td>12</td>
<td>96</td>
<td>129.92</td>
<td>122.31</td>
<td>105.36</td>
<td>75.29</td>
<td>66.85</td>
</tr>
<tr>
<td>14</td>
<td>112</td>
<td>138.21</td>
<td>129.94</td>
<td>111.95</td>
<td>80.22</td>
<td>71.49</td>
</tr>
<tr>
<td>16</td>
<td>128</td>
<td>145.93</td>
<td>137.04</td>
<td>118.08</td>
<td>84.81</td>
<td>75.82</td>
</tr>
<tr>
<td>18</td>
<td>144</td>
<td>153.19</td>
<td>143.72</td>
<td>123.84</td>
<td>89.13</td>
<td>79.88</td>
</tr>
<tr>
<td>20</td>
<td>160</td>
<td>160.05</td>
<td>150.03</td>
<td>129.29</td>
<td>93.21</td>
<td>83.72</td>
</tr>
<tr>
<td>22</td>
<td>176</td>
<td>166.59</td>
<td>156.03</td>
<td>134.47</td>
<td>97.10</td>
<td>87.38</td>
</tr>
<tr>
<td>24</td>
<td>192</td>
<td>172.83</td>
<td>161.77</td>
<td>139.42</td>
<td>100.82</td>
<td>90.88</td>
</tr>
<tr>
<td>26</td>
<td>208</td>
<td>178.82</td>
<td>167.28</td>
<td>144.18</td>
<td>104.38</td>
<td>94.23</td>
</tr>
<tr>
<td>28</td>
<td>224</td>
<td>184.58</td>
<td>172.57</td>
<td>148.75</td>
<td>107.81</td>
<td>97.46</td>
</tr>
<tr>
<td>30</td>
<td>240</td>
<td>190.15</td>
<td>177.69</td>
<td>153.17</td>
<td>111.12</td>
<td>100.58</td>
</tr>
</tbody>
</table>

^{581} Although in theory the hours should be all hours that infiltration is expected (i.e. all hours <55°F), the IL TAC has agreed to use the Equivalent Full Load Hours to keep the savings at a more conservative level.

^{582} From IECC 2012 Minimum Efficiency Requirements. For a 1 ton PTHP, COP = 2.9 – (0.026 * 12,000/1,000).
EXAMPLE

A mid-rise multi-family building located in the moderate terrain class and shielding class of Chicago, has 16 rooms on the 10th floor (80 feet high) with PTHPs that get covered with a cover and foam gasket during the heating months. The indoor temperature during the heating months is maintained at 74°F. The air infiltration and the related energy savings from the AC covers and seals are calculated as follows -

For Shielding Class 3 and Terrain Class 3,
A = 0.24, B = 0.85 and C = 0.2
Therefore,
\[ f_s = \frac{1}{3} \times (9.81 \text{ m/s}^2 \times 80 \text{ ft} \times 0.3048 \text{ m/ft} / 274.26 \text{ K})^{0.5} = 0.3 \text{ m/K}^{0.5} \]
\[ f_w = 0.24 \times 0.85 \times (80 \text{ ft} \times 0.3048 \text{ m/ft} / 10 \text{ m})^{0.2} = 0.24 \]
Total effective leakage area (ELA) = 16 units * 6 sq. in. = 96 sq. in.
\[ Q_{\text{infiltration}} = \text{ELA} \times 0.000645 \times (f_s^2 \times (T_{OA} - T_{SA}) + f_w^2 \times U^2)^{1/2} \times 2118.88 \]
\[ = 96 \times 0.000645 \times (0.3^2 \times (296.48 \text{ K} - 274.26 \text{ K}) + 0.24^2 \times 4.67^2)^{1/2} \times 2118.88 \]
\[ = 237 \text{ CFM} \]
\[ \Delta \text{kWh} = \frac{237 \times 1.08 \text{ Btu/hr.CFM.}^\circ \text{F} \times (74^\circ \text{F} - 33.99^\circ \text{F}) \times 1,685}{(3,412 \text{ Btu/kWh} \times 2.6)} \]
\[ = 1,945 \text{ kWh} \]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

As the savings occur during the winter season (non-peak), there are no demand savings associated with this measure.

NATURAL GAS SAVINGS

If the building is heated with gas, the natural gas savings are calculated as follows:
\[ \Delta \text{Therms} = (Q_{\text{infiltration}} \times 1.08 \text{ Btu/hr.CFM.}^\circ \text{F} \times (T_{OA} - T_{SA}) \times \text{EFLH}_{\text{heat}}) / (100,000 \text{ Btu/therm} \times \eta) \]
Where,
\[ \eta = \text{Efficiency of heating equipment.} \]
\[ \text{Collect} = \text{on site. If unknown, assume 80\text{%}}}^{583}. \]
\[ 100,000 = \text{Converts Btus to therms} \]
Other factors as defined above

Deemed per-unit savings per unit for the Multi-Family Building type for Shielding Class 3 and Terrain Class 3 are as follows:

<table>
<thead>
<tr>
<th>Multi-Family - Gas Savings per Unit (Therms/Unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Height</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

---

Multi-Family - Gas Savings per Unit (Therms/Unit)

<table>
<thead>
<tr>
<th>Floor</th>
<th>Height</th>
<th>Rockford</th>
<th>Chicago</th>
<th>Springfield</th>
<th>Belleville</th>
<th>Marion</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>48</td>
<td>11.04</td>
<td>10.46</td>
<td>9.01</td>
<td>6.35</td>
<td>5.54</td>
</tr>
<tr>
<td>7</td>
<td>56</td>
<td>11.69</td>
<td>11.06</td>
<td>9.53</td>
<td>6.74</td>
<td>5.90</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>12.30</td>
<td>11.62</td>
<td>10.01</td>
<td>7.10</td>
<td>6.24</td>
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<td>9</td>
<td>72</td>
<td>12.87</td>
<td>12.15</td>
<td>10.46</td>
<td>7.43</td>
<td>6.55</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>13.41</td>
<td>12.64</td>
<td>10.89</td>
<td>7.75</td>
<td>6.85</td>
</tr>
<tr>
<td>12</td>
<td>96</td>
<td>14.41</td>
<td>13.56</td>
<td>11.68</td>
<td>8.35</td>
<td>7.41</td>
</tr>
<tr>
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<td>112</td>
<td>15.33</td>
<td>14.41</td>
<td>12.41</td>
<td>8.90</td>
<td>7.93</td>
</tr>
<tr>
<td>16</td>
<td>128</td>
<td>16.18</td>
<td>15.20</td>
<td>13.09</td>
<td>9.40</td>
<td>8.41</td>
</tr>
<tr>
<td>18</td>
<td>144</td>
<td>16.99</td>
<td>15.94</td>
<td>13.73</td>
<td>9.88</td>
<td>8.86</td>
</tr>
<tr>
<td>20</td>
<td>160</td>
<td>17.75</td>
<td>16.64</td>
<td>14.34</td>
<td>10.34</td>
<td>9.28</td>
</tr>
<tr>
<td>22</td>
<td>176</td>
<td>18.47</td>
<td>17.30</td>
<td>14.91</td>
<td>10.77</td>
<td>9.69</td>
</tr>
<tr>
<td>24</td>
<td>192</td>
<td>19.16</td>
<td>17.94</td>
<td>15.46</td>
<td>11.18</td>
<td>10.08</td>
</tr>
<tr>
<td>26</td>
<td>208</td>
<td>19.83</td>
<td>18.55</td>
<td>15.99</td>
<td>11.57</td>
<td>10.45</td>
</tr>
<tr>
<td>28</td>
<td>224</td>
<td>20.47</td>
<td>19.14</td>
<td>16.50</td>
<td>11.96</td>
<td>10.81</td>
</tr>
<tr>
<td>30</td>
<td>240</td>
<td>21.09</td>
<td>19.70</td>
<td>16.98</td>
<td>12.32</td>
<td>11.15</td>
</tr>
</tbody>
</table>

**EXAMPLE**

A gas-heated mid-rise multi-family building located in the moderate terrain class and shielding class of Chicago, has 16 rooms on the 10th floor (80 feet high) with room air conditioners that get covered with an AC cover and foam gasket during the heating months. The indoor temperature during the heating months is maintained at 74°F. The air infiltration and the related therm savings from the AC covers and seals are calculated as follows.

For Shielding Class 3 and Terrain Class 3,

\[ A = 0.24, \quad B = 0.85 \text{ and } C = 0.2 \]

Therefore,

\[ f_s = \frac{1}{3} \times (9.81 \text{ m/s}^2 \times 80 \text{ ft} \times 0.3048 \text{ m/ft} / 274.26 \text{ K})^{0.5} = 0.3 \text{ m/K}^{0.5} \text{s} \]

\[ f_w = 0.24 \times 0.85 \times (80 \text{ ft} \times 0.3048 \text{ m/ft} / 10 \text{ m})^{0.2} = 0.24 \]

Total effective leakage area (ELA) = 16 units * 6 sq.in = 96 sq. in

\[ Q_{\text{infiltration}} = \text{ELA} \times 0.000645 \times (f_s^2 \times (T_{\text{OA}} - T_{\text{SA}}) + f_w^2 \times U^2)^{1/2} \times 2118.88 \]

\[ = 96 \times 0.000645 \times (0.3^2 \times (296.48 \text{ K} - 274.26 \text{ K}) + 0.24^2 \times 4.67^2)^{1/2} \times 2118.88 \]

\[ = 237 \text{ CFM} \]

\[ \Delta \text{Therms} = (237 \times 1.08 \text{ Btu/hr.CFM.}^\circ\text{F} \times (74^\circ\text{F} - 33.99^\circ\text{F}) \times 1,685) / (100,000 \text{ Btu/therm} \times 80\% ) \]

\[ = 216 \text{ therms} \]

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A
**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** CI-HVC-CRAC-V01-180101

**REVIEW DEADLINE:** 1/1/2023
4.4.39 High Temperature Heating and Ventilation (HTHV) Direct Fired Heater

DESCRIPTION

This measure applies to 100% outside air, high temperature heating and ventilation (HTHV) direct fired gas heaters. These units replace unit heaters (indirect gas fired or steam coil) or rooftop units in warehouses which suffer from extreme temperature stratification, minimal controls and reduced heating efficiencies.

Warehouses have high ceilings (~30 ft high), and suffer from stratification of air. The warm air rises and remains near the roof, which keeps the thermostat from reaching its desired setpoint. This increases the run hours of the heating unit and causes discomfort among the occupants. The HTHV units have high pressure fans that direct high temperature and high velocity air towards the floor and thus help minimize temperature stratification. On average, a 30 ft high warehouse could reduce its linear stratification from 0.53°F/ft to 0.13°F/ft, thus maintaining a more uniform temperature in the room and reducing the operating hours of the heating unit.

Since the HTHV units are direct fired, they also have improved efficiencies of 92% compared to 80% for a typical indirect fired unit heater or rooftop unit. They transfer the latent heat of the flue gases into the space instead of venting it out.

This measure only applies to high ceiling warehouses that do not have any other destratification technologies installed (i.e. destratification fans, air rotation units etc.). New HTHV units must be the warehouse’s primary heat source.

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

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment must be a 100% outside air, HTHV direct fired gas heater, with a discharge temperature greater than or equal to 150°F, a temperature rise greater than or equal to 140°F, and an efficiency exceeding 92%.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment must be an indirect fired gas or steam unit heater or a rooftop unit used as the primary space heating source. Warehouses with existing destratification technologies (high volume, low speed fans or air turnover units) do not qualify for this measure.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 15 years.

DEEMED MEASURE COST

The measure cost should be based on a contractor’s evaluation of the project scope and may vary significantly on a project to project basis. If unknown, for early replacement or retrofit projects, assume $14.50/MBtu/hr (material cost for an HTHV unit) or $26/MBTU/h (sum of material and installation cost). The incremental measure cost, assuming a baseline of standard efficiency unit heaters, is $7.43/MBtu/hr (material cost).

---

585 Average costs from CLEAResult’s evaluation of 9 different projects in the Chicagoland area.
LOADSHAPE

Loadshape C04: Commercial Electric Heating

COINCIDENCE FACTOR

Assumed to be 0.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

HTHV units may increase the facility’s electric energy consumption due to high pressure motors that supply air at higher velocity.

\[ \Delta \text{kWh} = - \text{kWh/HDD} \times \text{HDD} \]

Where:

- **kWh/HDD** = increase in electric energy consumption due to HTHV fan motor
  - \( = 1.04^{587} \)
- **HDD** = heating degree days

<table>
<thead>
<tr>
<th>Zone</th>
<th>City</th>
<th>HDD588</th>
<th>ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rockford</td>
<td>4,272</td>
<td>(4,443)</td>
</tr>
<tr>
<td>2</td>
<td>Chicago</td>
<td>4,029</td>
<td>(4,190)</td>
</tr>
<tr>
<td>3</td>
<td>Springfield</td>
<td>3,406</td>
<td>(3,542)</td>
</tr>
<tr>
<td>4</td>
<td>Belleville</td>
<td>2,515</td>
<td>(2,616)</td>
</tr>
<tr>
<td>5</td>
<td>Marion</td>
<td>2,546</td>
<td>(2,648)</td>
</tr>
</tbody>
</table>

Although HTHV fan motors have a higher power draw, they also result in decreased heating equipment operating time, potentially offsetting some of the increase in electrical energy consumption. Therefore, if replacing heating equipment other than unit heaters, a custom evaluation may be necessary to determine if there is an increase in electrical energy consumption.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Since HTHV units operate during the winter (non-peak) season, there are no demand savings associated with this measure.

NATURAL GAS SAVINGS

Custom calculation below, otherwise use a deemed savings factor from the table that follows.

\[ \Delta \text{Therms} = (\text{FLH}_{\text{base}} \times \text{Cap}_{\text{base}} / (\eta_{\text{base}} \times 100)) - (\text{FLH}_{\text{eff}} \times \text{Cap}_{\text{eff}} / (\eta_{\text{eff}} \times 100)) \]

Where:

587 Based on data collected in “Field Demonstation of High Efficiency Gas Heaters”, prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. This study replaced four standard unit heaters with HTHV units, and the electrical energy increased from 0.4 kWh/HDD to 1.44 kWh/HDD. Therefore savings are assumed to be 1.04 kWh/HDD.

588 30-year normals from the National Climactic Data Center (NCDC), assuming base temperature 55.
FLH\textsubscript{base} = LF\textsubscript{base} * Hours

FLH\textsubscript{eff} = LF\textsubscript{eff} * Hours

Hours = Annual operating hours of the unit, calculated as total number of hours when outside air temperature is less than 55°F. This can be adjusted based on the facility’s occupancy schedule.

LF\textsubscript{base} = load factor of baseline unit heater

= \frac{(Q_{\text{inf,base}} + Q_{\text{w,base}} + Q_{\text{r,base}})}{(\text{Cap}\textsubscript{base} * 100)}

LF\textsubscript{eff} = load factor of HTHV heater

= \frac{(Q_{\text{inf,eff}} + Q_{\text{w,eff}} + Q_{\text{r,eff}})}{(\text{Cap}\textsubscript{eff} * 100)}

\text{Cap}\textsubscript{base} = existing heating unit input capacity (MBtu/hr)

= can be collected on site, or assumed to be the same as HTHV unit capacity, \text{Cap}\textsubscript{eff}

\text{Cap}\textsubscript{eff} = HTHV unit input capacity (MBtu/hr)

= can be collected on site or from specification sheets

\eta\textsubscript{base} = efficiency of existing heating unit

= collected from equipment nameplate or assumed as 70% for steam unit heaters, 80% for gas fired unit heaters, and 84% for rooftop units

\eta\textsubscript{eff} = efficiency of HTHV unit

= collected from equipment nameplate or assumed as 92%

100 \ = converts MBtu to therms

See table below for savings inputs.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Existing Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperatures</td>
<td>T\textsubscript{setpoint} = collected on site, or assumed as 65°F</td>
</tr>
<tr>
<td>Setpoint Temperature (°F)</td>
<td>Either collected on site when the existing unit is in operation with an infrared gun, or assumed as:</td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{c,base} = T\textsubscript{setpoint} + 0.53°F/ft * Height</td>
</tr>
<tr>
<td>Ceiling Temperature\textsuperscript{590} (°F)</td>
<td>Either collected on site when the proposed unit is in operation with an infrared gun, or assumed as:</td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{c,eff} = T\textsubscript{setpoint} + 2 to 4°F</td>
</tr>
<tr>
<td>Average Room Temperature (°F)</td>
<td>T\textsubscript{r,base} = (T\textsubscript{setpoint} + T\textsubscript{c,base})/2</td>
</tr>
<tr>
<td></td>
<td>T\textsubscript{r,eff} = (T\textsubscript{setpoint} + T\textsubscript{c,eff})/2</td>
</tr>
<tr>
<td>Outside Air Temperature (°F)</td>
<td>T\textsubscript{OA} , from local weather data\textsuperscript{591}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heat Loads</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration Load\textsuperscript{592}:</td>
<td>Q_{\text{inf,base}} = 0.04CFM/ft\textsuperscript{2} * (Wall Surface Area + Roof Surface Area) * 1.08 * (T_{r,base} - T_{OA})</td>
</tr>
<tr>
<td></td>
<td>Q_{\text{inf,eff}} = 0.04CFM/ft\textsuperscript{2} * (Wall Surface Area + Roof Surface Area) * 1.08 * (T_{r,eff} - T_{OA})</td>
</tr>
</tbody>
</table>

\textsuperscript{589} Efficiency of existing systems assumed from ASHRAE 90.1 – 2010 and manufacturer’s specification sheets for various equipment. Steam unit heaters have a lower efficiency due to steam distribution losses.

\textsuperscript{590} Baseline stratification rate is based on data collected in “Field Demonstration of High Efficiency Gas Heaters”, prepared for Better Buildings Alliance, US. DOE, Jim Young, Navigant Consulting, 2014. The study also verifies that the proposed ceiling temperature can be maintained within 2-4°F of the setpoint.

\textsuperscript{591} Use Typical Meteorological Year (TMY3) data from NREL available here: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

\textsuperscript{592} Typical infiltration rate assumed from Infiltration Modeling Guidelines for Commercial Building Energy Analysis, prepared for US. DOE by Pacific Northwestern National Laboratory, 2009
### Wall Conduction Load\(^\text{593}\):

\[
Q_{w,\text{base}} = \frac{1}{\text{R-value}_{\text{wall}}} \times (\text{Wall Surface Area} \times 1.08 \times (T_r,\text{base} - T_{\text{OA}}))
\]

Where \(\text{R-value}_{\text{wall}}\) = the insulation value of the wall. It can be collected on site, or assumed as \(\text{R-15}\).

\[
Q_{w,\text{eff}} = \frac{1}{\text{R-value}_{\text{wall}}} \times (\text{Wall Surface Area} \times 1.08 \times (T_r,\text{eff} - T_{\text{OA}}))
\]

Where \(\text{R-value}_{\text{wall}}\) = the insulation value of the wall. It can be collected on site, or assumed as \(\text{R-15}\).

### Roof Conduction Load:

\[
Q_{r,\text{base}} = \frac{1}{\text{R-value}_{\text{roof}}} \times (\text{Roof Surface Area} \times 1.08 \times (T_r,\text{base} - T_{\text{OA}}))
\]

Where \(\text{R-value}_{\text{roof}}\) = the insulation value of the roof. It can be collected on site, or assumed as \(\text{R-20}\).

\[
Q_{r,\text{eff}} = \frac{1}{\text{R-value}_{\text{roof}}} \times (\text{Roof Surface Area} \times 1.08 \times (T_r,\text{eff} - T_{\text{OA}}))
\]

Where \(\text{R-value}_{\text{roof}}\) = the insulation value of the roof. It can be collected on site, or assumed as \(\text{R-20}\).

### Surface Areas

**Roof Surface Area:**

Collected on site or assumed as:

- = facility area in sq.ft.
- If facility area is unknown, assume facility area\(^\text{594}\) = 41.4 sq. ft./MBtu/hr * Cap\(_{\text{eff}}\)

**Wall Surface Area:**

Collected on site or assumed as:

- = (Height * Length + Height * Width) * 2
- Where:
  - Length, Height and Width (feet) of the facility can be collected on site. If unknown, assume:
  - Length = Width = \((\text{Facility Area})^{1/2}\)
  - Height = 25 ft
- If facility area is unknown, assume facility area = 41.4 sq. ft./MBtu/hr * Cap\(_{\text{eff}}\)

The default values from the table above were used to calculate the deemed savings values in the table below. Savings are provided for various rated input capacity ranges and weather stations.

<table>
<thead>
<tr>
<th>Cap(_{\text{eff}}) (MBtu/hr)</th>
<th>Average Cap(_{\text{eff}}) (MBtu/hr)</th>
<th>Nearest Weather Station</th>
<th>ΔTherms (Baseline Equipment: Steam Fired Unit Heaters)</th>
<th>ΔTherms (Baseline Equipment: Gas Fired Unit Heaters)</th>
<th>ΔTherms (Baseline Equipment: Rooftop Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 &gt; Cap(_{\text{eff}}) ≥ 500</td>
<td>400</td>
<td>Rockford</td>
<td>3,120</td>
<td>1,996</td>
<td>1,620</td>
</tr>
<tr>
<td>500 &gt; Cap(_{\text{eff}}) ≥ 900</td>
<td>757</td>
<td>Rockford</td>
<td>5,208</td>
<td>3,346</td>
<td>2,725</td>
</tr>
<tr>
<td>900 &gt; Cap(_{\text{eff}}) ≥ 1,000</td>
<td>950</td>
<td>Rockford</td>
<td>6,280</td>
<td>4,047</td>
<td>3,297</td>
</tr>
<tr>
<td>1,000 &gt; Cap(_{\text{eff}}) ≥ 1,400</td>
<td>1,200</td>
<td>Rockford</td>
<td>7,656</td>
<td>4,932</td>
<td>4,020</td>
</tr>
<tr>
<td>1,400 &gt; Cap(_{\text{eff}}) ≥ 1,600</td>
<td>1,499</td>
<td>Rockford</td>
<td>9,249</td>
<td>5,966</td>
<td>4,872</td>
</tr>
<tr>
<td>1,600 &gt; Cap(_{\text{eff}}) ≥ 2,100</td>
<td>1,850</td>
<td>Rockford</td>
<td>11,100</td>
<td>7,160</td>
<td>5,865</td>
</tr>
<tr>
<td>2,100 &gt; Cap(_{\text{eff}}) ≥ 2,400</td>
<td>2,200</td>
<td>Rockford</td>
<td>12,914</td>
<td>8,338</td>
<td>6,820</td>
</tr>
<tr>
<td>Cap(_{\text{eff}}) ≥ 2,400</td>
<td>2,718</td>
<td>Rockford</td>
<td>15,547</td>
<td>10,084</td>
<td>8,236</td>
</tr>
<tr>
<td>300 &gt; Cap(_{\text{eff}}) ≥ 500</td>
<td>400</td>
<td>Chicago</td>
<td>2,820</td>
<td>1,824</td>
<td>1,488</td>
</tr>
<tr>
<td>500 &gt; Cap(_{\text{eff}}) ≥ 900</td>
<td>757</td>
<td>Chicago</td>
<td>4,709</td>
<td>3,058</td>
<td>2,506</td>
</tr>
<tr>
<td>900 &gt; Cap(_{\text{eff}}) ≥ 1,000</td>
<td>950</td>
<td>Chicago</td>
<td>5,681</td>
<td>3,696</td>
<td>3,031</td>
</tr>
<tr>
<td>1,000 &gt; Cap(_{\text{eff}}) ≥ 1,400</td>
<td>1,200</td>
<td>Chicago</td>
<td>6,924</td>
<td>4,512</td>
<td>3,696</td>
</tr>
<tr>
<td>1,400 &gt; Cap(_{\text{eff}}) ≥ 1,600</td>
<td>1,499</td>
<td>Chicago</td>
<td>8,364</td>
<td>5,456</td>
<td>4,482</td>
</tr>
<tr>
<td>1,600 &gt; Cap(_{\text{eff}}) ≥ 2,100</td>
<td>1,850</td>
<td>Chicago</td>
<td>10,046</td>
<td>6,549</td>
<td>5,384</td>
</tr>
<tr>
<td>2,100 &gt; Cap(_{\text{eff}}) ≥ 2,400</td>
<td>2,200</td>
<td>Chicago</td>
<td>11,682</td>
<td>7,634</td>
<td>6,292</td>
</tr>
<tr>
<td>Cap(_{\text{eff}}) ≥ 2,400</td>
<td>2,718</td>
<td>Chicago</td>
<td>14,079</td>
<td>9,214</td>
<td>7,583</td>
</tr>
<tr>
<td>300 &gt; Cap(_{\text{eff}}) ≥ 500</td>
<td>400</td>
<td>Springfield</td>
<td>2,452</td>
<td>1,588</td>
<td>1,300</td>
</tr>
</tbody>
</table>

\(^{593}\) Roof and Wall Insulation R-values are based on ASHRAE 90.1- 2010. (Jim Young 2014) (K. Gowri 2009)

\(^{594}\) Based on DOE’s Commercial Prototype Modeled Warehouse building (in Chicago), found here:  
[https://www.energycodes.gov/commercial-prototype-building-models](https://www.energycodes.gov/commercial-prototype-building-models)
### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

N/A

### Measure Code: CI-HVC-HTHV-V01-180101

### Review Deadline: 1/1/2023

<table>
<thead>
<tr>
<th>Cap_{eff} (MBtu/hr)</th>
<th>Average Cap_{eff} (MBtu/hr)</th>
<th>Nearest Weather Station</th>
<th>ΔTherms (Baseline Equipment: Steam Fired Unit Heaters)</th>
<th>ΔTherms (Baseline Equipment: Gas Fired Unit Heaters)</th>
<th>ΔTherms (Baseline Equipment: Rooftop Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 &gt; Cap_{eff} ≥ 900</td>
<td>757</td>
<td>Springfield</td>
<td>4,095</td>
<td>2,665</td>
<td>2,188</td>
</tr>
<tr>
<td>900 &gt; Cap_{eff} ≥ 1,000</td>
<td>950</td>
<td>Springfield</td>
<td>4,950</td>
<td>3,221</td>
<td>2,651</td>
</tr>
<tr>
<td>1,000 &gt; Cap_{eff} ≥ 1,400</td>
<td>1,200</td>
<td>Springfield</td>
<td>6,024</td>
<td>3,936</td>
<td>3,240</td>
</tr>
<tr>
<td>1,400 &gt; Cap_{eff} ≥ 1,600</td>
<td>1,499</td>
<td>Springfield</td>
<td>7,285</td>
<td>4,767</td>
<td>3,912</td>
</tr>
<tr>
<td>1,600 &gt; Cap_{eff} ≥ 2,100</td>
<td>1,850</td>
<td>Springfield</td>
<td>8,732</td>
<td>5,717</td>
<td>4,718</td>
</tr>
<tr>
<td>2,100 &gt; Cap_{eff} ≥ 2,400</td>
<td>2,200</td>
<td>Springfield</td>
<td>10,164</td>
<td>6,666</td>
<td>5,500</td>
</tr>
<tr>
<td>Cap_{eff} ≥ 2,400</td>
<td>2,718</td>
<td>Springfield</td>
<td>12,258</td>
<td>8,045</td>
<td>6,632</td>
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<tr>
<td>300 &gt; Cap_{eff} ≥ 500</td>
<td>400</td>
<td>Belleville</td>
<td>2,456</td>
<td>1,604</td>
<td>1,320</td>
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<tr>
<td>500 &gt; Cap_{eff} ≥ 900</td>
<td>757</td>
<td>Belleville</td>
<td>4,103</td>
<td>2,687</td>
<td>2,218</td>
</tr>
<tr>
<td>900 &gt; Cap_{eff} ≥ 1,000</td>
<td>950</td>
<td>Belleville</td>
<td>4,950</td>
<td>3,249</td>
<td>2,689</td>
</tr>
<tr>
<td>1,000 &gt; Cap_{eff} ≥ 1,400</td>
<td>1,200</td>
<td>Belleville</td>
<td>6,036</td>
<td>3,972</td>
<td>3,276</td>
</tr>
<tr>
<td>1,400 &gt; Cap_{eff} ≥ 1,600</td>
<td>1,499</td>
<td>Belleville</td>
<td>7,300</td>
<td>4,812</td>
<td>3,972</td>
</tr>
<tr>
<td>1,600 &gt; Cap_{eff} ≥ 2,100</td>
<td>1,850</td>
<td>Belleville</td>
<td>8,751</td>
<td>5,772</td>
<td>4,773</td>
</tr>
<tr>
<td>2,100 &gt; Cap_{eff} ≥ 2,400</td>
<td>2,200</td>
<td>Belleville</td>
<td>10,186</td>
<td>6,732</td>
<td>5,566</td>
</tr>
<tr>
<td>Cap_{eff} ≥ 2,400</td>
<td>2,718</td>
<td>Belleville</td>
<td>12,285</td>
<td>8,127</td>
<td>6,713</td>
</tr>
<tr>
<td>300 &gt; Cap_{eff} ≥ 500</td>
<td>400</td>
<td>Marion</td>
<td>2,180</td>
<td>1,444</td>
<td>1,200</td>
</tr>
<tr>
<td>500 &gt; Cap_{eff} ≥ 900</td>
<td>757</td>
<td>Marion</td>
<td>3,649</td>
<td>2,430</td>
<td>2,021</td>
</tr>
<tr>
<td>900 &gt; Cap_{eff} ≥ 1,000</td>
<td>950</td>
<td>Marion</td>
<td>4,408</td>
<td>2,936</td>
<td>2,442</td>
</tr>
<tr>
<td>1,000 &gt; Cap_{eff} ≥ 1,400</td>
<td>1,200</td>
<td>Marion</td>
<td>5,364</td>
<td>3,576</td>
<td>2,988</td>
</tr>
<tr>
<td>1,400 &gt; Cap_{eff} ≥ 1,600</td>
<td>1,499</td>
<td>Marion</td>
<td>6,491</td>
<td>4,332</td>
<td>3,613</td>
</tr>
<tr>
<td>1,600 &gt; Cap_{eff} ≥ 2,100</td>
<td>1,850</td>
<td>Marion</td>
<td>7,789</td>
<td>5,217</td>
<td>4,348</td>
</tr>
<tr>
<td>2,100 &gt; Cap_{eff} ≥ 2,400</td>
<td>2,200</td>
<td>Marion</td>
<td>9,064</td>
<td>6,072</td>
<td>5,082</td>
</tr>
<tr>
<td>Cap_{eff} ≥ 2,400</td>
<td>2,718</td>
<td>Marion</td>
<td>10,926</td>
<td>7,339</td>
<td>6,116</td>
</tr>
</tbody>
</table>
4.5 Lighting End Use

The commercial lighting measures use a standard set of variables for hours or use, waste heat factors, coincident factors and HVAC interaction effects. This table has been developed based on information provided by the various stakeholders. For ease of review, the table is included here and referenced in each measure.

The building characteristics can be found in the reference table named “EFLH Building Descriptions Updated 2014-11-21.xlsx”.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.
### Exterior Lighting Hours – dusk to business close

\[
\text{Hours} = (6.19 \times \text{Days}) + (\%\text{Adj} \times \text{Days})
\]

Where:

- \(6.19\) = Average hours per day between dusk and midnight\(^{601}\)
- \(\%\text{Adj}\) = Percent adjustment dependent on hour closing\(^{602}\)
- \(\text{Days}\) = Days of business operation
- \(\) = Actual

Exterior Lighting Hours – dusk to business close

- See calculation below

- **Low-Use Small Business**
  - Annual Operating Hours: 2,954
  - Annual Operating Hours: 2,954
  - Waste Heat Cooling Energy WHFe: 1.31
  - Waste Heat Cooling Demand WHFd: 1.53
  - Coincidence Factor CF:\(^{598}\): 0.66
  - Waste Heat Gas Heating IFTherms:\(^{599}\): 0.023
  - Waste Heat Electric Resistance Heating IFkWh:\(^{600}\): 0.524

- **Uncooled Building**
  - Annual Operating Hours: Varies
  - Annual Operating Hours: Varies
  - Waste Heat Cooling Energy WHFe: 1.00
  - Waste Heat Cooling Demand WHFd: 1.00
  - Coincidence Factor CF:\(^{598}\): 0.66
  - Waste Heat Gas Heating IFTherms:\(^{599}\): 0.014
  - Waste Heat Electric Resistance Heating IFkWh:\(^{600}\): 0.320

- **Refrigerated Cases**
  - Annual Operating Hours: 5,802
  - Annual Operating Hours: n/a
  - Waste Heat Cooling Energy WHFe: 1.29
  - Waste Heat Cooling Demand WHFd: 1.29
  - Coincidence Factor CF:\(^{598}\): 0.00
  - Waste Heat Gas Heating IFTherms:\(^{599}\): 0.00
  - Waste Heat Electric Resistance Heating IFkWh:\(^{600}\): 0.00

- **Freezer Cases**
  - Annual Operating Hours: 5,802
  - Annual Operating Hours: n/a
  - Waste Heat Cooling Energy WHFe: 1.50
  - Waste Heat Cooling Demand WHFd: 1.5
  - Coincidence Factor CF:\(^{598}\): 0.69
  - Waste Heat Gas Heating IFTherms:\(^{599}\): 0.00
  - Waste Heat Electric Resistance Heating IFkWh:\(^{600}\): 0.00

---

\(^{601}\) Calculated using the eQuest model by finding the total number of hours of exterior lighting consumption between dusk and midnight and dividing by 365 (2261 / 365 = 6.19 hours per day).

\(^{602}\) See "IL TRM Ext Lighting.xlsx" for calculation.
For example a business open until 8pm, 260 days per year, would assume:

\[
\text{Hours} = (6.19 \times 260) + (-400\% \times 260) = 569.4 \text{ hours}
\]
4.5.1 Commercial ENERGY STAR Compact Fluorescent Lamp (CFL)

DESCRIPTION

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf). The efficacy requirements can not currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a commercial location. If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used, and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used.

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard qualified compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours) by the run hours. For example using Miscellaneous at 3,612 hours would give 2.8 years. When the number of years exceeds 2021, the number of years to that date should be used.

---

603 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See ‘RESvCI Split_112016.xls’.

604 Based upon final weighted (by sales volume) average of the BILD program (ComEd’s commercial lighting program) for PY 4 and PY5 and PY6.

605 Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.
**DEEMED MEASURE COST**

The incremental capital cost assumption for all bulbs under 2600 lumens is $1.20\(^{606}\).

For bulbs over 2600 lumens the assumed incremental capital cost is $5.

**LOADSHAPE**

- Loadshape C06 - Commercial Indoor Lighting
- Loadshape C07 - Grocery/Conv. Store Indoor Lighting
- Loadshape C08 - Hospital Indoor Lighting
- Loadshape C09 - Office Indoor Lighting
- Loadshape C10 - Restaurant Indoor Lighting
- Loadshape C11 - Retail Indoor Lighting
- Loadshape C12 - Warehouse Indoor Lighting
- Loadshape C13 - K-12 School Indoor Lighting
- Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
- Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
- Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
- Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
- Loadshape C18 - Industrial Indoor Lighting
- Loadshape C19 - Industrial Outdoor Lighting
- Loadshape C20 - Commercial Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta \text{kWh} = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{Hours} \times \text{WHFe}
\]

Where:

- \(\text{WattsBase}\) = Actual (if retrofit measure) or based on lumens of CFL bulb and program year installed:

<table>
<thead>
<tr>
<th>Minimum Lumens</th>
<th>Maximum Lumens</th>
<th>Incandescent Equivalent Post-EISA 2007 (WattsBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5280</td>
<td>6209</td>
<td>300</td>
</tr>
<tr>
<td>3000</td>
<td>5279</td>
<td>200</td>
</tr>
</tbody>
</table>

\(^{606}\) Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
Minimum Lumens | Maximum Lumens | Incandescent Equivalent Post-EISA 2007 (WattsBase)
---|---|---
2601 | 2999 | 150
1490 | 2600 | 72
1050 | 1489 | 53
750 | 1049 | 43
310 | 749 | 29
250 | 309 | 25

WattsEE = Actual wattage of CFL purchased or installed
ISR = In Service Rate or the percentage of units rebated that get installed.

=100%\(^{607}\) if application form completed with sign off that equipment is not placed into storage

If sign off form not completed assume the following 3 year ISR assumptions:

<table>
<thead>
<tr>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>71.2(^{608})%</td>
<td>14.5%</td>
<td>12.3%</td>
<td>98.0(^{609})%</td>
</tr>
</tbody>
</table>

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type\(^{610}\). If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in an office and sign off form provided:

\[
\Delta kWh = \left(\frac{43 - 14}{1000}\right) \times 1.0 \times 3088 \times 1.25
\]

\[= 111.9 \text{ kWh}\]

\(^{607}\) Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an "In-Service Rate" when commercial customers complete an application form.

\(^{608}\) 1st year in service rate is based upon review of PY4-6 evaluations from ComEd’s commercial lighting program (BILD) (see ‘IL Commercial Lighting ISR_2014.xls’ for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

\(^{609}\) The 98% Lifetime ISR assumption is based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report; Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact.

\(^{610}\) Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.
**HEATING PENALTY**

If electrically heated building:

\[ \Delta kWh_{\text{heatpenalty}}^{611} = \left(\frac{(\text{WattsBase}-\text{WattsEE})}{1000}\right) \times \text{ISR} \times \text{Hours} \times -\text{IFkWh} \]

Where:

- \( \text{IFkWh} \) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 14W standard CFL is installed in a heat pump heated office and sign off form provided:

\[ \Delta kWh_{\text{heatpenalty}} = \left(\frac{(43 - 14)}{1000}\right) \times 1.0 \times 3088 \times -0.183 \]

\[ = -16.4 \, \text{kWh} \]

**DEFERRED INSTALLS**

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- **Year 1 (Purchase Year) installs:** Characterized using assumptions provided above or evaluated assumptions if available.
- **Year 2 and 3 installs:** Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.
  
  The NTG factor for the Purchase Year should be applied.

For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen) purchased and using miscellaneous hours assumption.

\[ \Delta kWh_{1\text{st year installs}} = \left(\frac{43 - 14}{1000}\right) \times 0.755 \times 3612 \times 1.06 \]

\[ = 83.8 \, \text{kWh} \]

\[ \Delta kWh_{2\text{nd year installs}} = \left(\frac{43 - 14}{1000}\right) \times 0.121 \times 3612 \times 1.06 \]

\[ = 13.4 \, \text{kWh} \]

\[ \Delta kWh_{3\text{rd year installs}} = \left(\frac{43 - 14}{1000}\right) \times 0.103 \times 3612 \times 1.06 \]

\[ = 11.4 \, \text{kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \left(\frac{(\text{WattsBase}-\text{WattsEE})}{1000}\right) \times \text{ISR} \times \text{WHFd} \times \text{CF} \]

Where:

\[ ^{611} \text{Negative value because this is an increase in heating consumption due to the efficient lighting.} \]
WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, a 14W standard CFL is installed in an office and sign off form provided:

ΔkW = ((43 - 14)/1000)*1.0*1.3*0.66
     = 0.025kW

NATURAL GAS ENERGY SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

ΔTherms\textsuperscript{612} = (((WattsBase - WattsEE)/1000) * ISR * Hours) - IFTherms

Where:

IFTherms = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, a 14W standard CFL is installed in an office and sign off form provided:

ΔTherms = (((43 - 14)/1000)* 1.0*3088*-0.016
         = - 1.4 Therms

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

<table>
<thead>
<tr>
<th>Replacement Period (years)\textsuperscript{613}</th>
<th>Replacement Cost\textsuperscript{614}</th>
</tr>
</thead>
<tbody>
<tr>
<td>= 1000 / Hours</td>
<td>$1.25</td>
</tr>
</tbody>
</table>

\textsuperscript{612} Negative value because this is an increase in heating consumption due to the efficient lighting.

\textsuperscript{613} Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

\textsuperscript{614} Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**Measure Code:** CI-LTG-CCFL-V07-180101

**Review Deadline:** 1/1/2020
4.5.2 Fluorescent Delamping

**DESCRIPTION**

This measure addresses the permanent removal of existing 8', 4', 3' and 2' fluorescent lamps. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture. This measure is applicable when retrofitting from T12 lamps to T8 lamps or simply removing lamps from a T8 fixture. Removing lamps from a T12 fixture that is not being retrofitted with T8 lamps are not eligible for this incentive.

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations. A pre-approval application is required for lamp removal projects.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

Savings are defined on a per removed lamp basis. The retrofit wattage (efficient conditioned) is therefore assumed to be zero. The savings numbers provided below are for the straight lamp removal measures, as well as the lamp removal and install reflector measures. The lamp installed/retrofit is captured in another measure.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is either a T12 or a T8 lamp with default wattages provided below. Note, if the program does not allow for the lamp type to be known, then a T12:T8 weighting of 80%:20% can be applied.\(^{615}\)

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 11 years per DEER 2005.

**DEEMED MEASURE COST**

The incremental capital cost is provided in the table below:

<table>
<thead>
<tr>
<th>Measure Category</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-Foot Lamp Removal</td>
<td>$16.00</td>
<td>ComEd/KEMA regression(^{616})</td>
</tr>
<tr>
<td>4-Foot Lamp Removal</td>
<td>$12.00</td>
<td>ICF Portfolio Plan</td>
</tr>
<tr>
<td>8-Foot Lamp Removal with reflector</td>
<td>$30.00</td>
<td>KEMA Assumption</td>
</tr>
<tr>
<td>4-Foot Lamp Removal with reflector</td>
<td>$25.00</td>
<td>KEMA Assumption</td>
</tr>
<tr>
<td>2-Foot or 3-Foot Removal</td>
<td>$12.35</td>
<td>KEMA Assumption</td>
</tr>
<tr>
<td>2-Foot or 3-Foot Removal with reflector</td>
<td>$25.70</td>
<td>KEMA Assumption</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

- Loadshape C06 - Commercial Indoor Lighting
- Loadshape C07 - Grocery/Conv. Store Indoor Lighting
- Loadshape C08 - Hospital Indoor Lighting

---

\(^{615}\) Based on ComEd’s estimate of lamp type saturation.

\(^{616}\) Based on the assessment of active projects in the 2008-09 ComEd Smart Ideas Program. See files “ltg costs 12-10-10.xl.” and “Lighting Unit Costs 102605.doc”
Loadshape C9 - Office Indoor Lighting  
Loadshape C10 - Restaurant Indoor Lighting  
Loadshape C11 - Retail Indoor Lighting  
Loadshape C12 - Warehouse Indoor Lighting  
Loadshape C13 - K-12 School Indoor Lighting  
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)  
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)  
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)  
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)  
Loadshape C18 - Industrial Indoor Lighting  
Loadshape C19 - Industrial Outdoor Lighting  
Loadshape C20 - Commercial Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

---

**Algorithm**

**Calculation of Savings**

**Electric Energy Savings**

\[ \Delta \text{kWh} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{WHFe} \]

Where:

- **WattsBase** = Assume wattage reduction of lamp removed
- **WattsEE** = 0
- **ISR** = In Service Rate or the percentage of units rebated that get installed.

<table>
<thead>
<tr>
<th>Wattage of lamp removed</th>
<th>Weighted average</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T8</strong></td>
<td><strong>T12</strong></td>
</tr>
<tr>
<td>8-ft T8</td>
<td>38.6</td>
</tr>
<tr>
<td>4-ft T8</td>
<td>19.4</td>
</tr>
<tr>
<td>3-ft T8</td>
<td>14.6</td>
</tr>
<tr>
<td>2-ft T8</td>
<td>9.8</td>
</tr>
</tbody>
</table>

617 Default wattage reduction is based on averaging the savings from moving from a 2 to 1, 3 to 2 and 4 to 3 lamp fixture, as provided in the Standard Performance Contract Procedures Manual: Appendix B: Table of Standard Fixture Wattages (http://www.sce.com/NR/rdonlyres/7A345F0-A337-439B-9607-10A016D32D4B/0/spc_B_Std Fixture Watts.pdf). An adjustment is made to the T8 delamped fixture to account for the significant increase in ballast factor. See 'Delamping calculation.xls' for details.
=100% if application form completed with sign off that equipment permanently removed and disposed of.

**Hours**

= Average hours of use per year are provided in Reference Table in Section 4.5. If unknown use the Miscellaneous value.

**WHFe**

= Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

<table>
<thead>
<tr>
<th>For example, delamping a 4 ft T8 fixture in an office building:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔkWh = ((19.4 - 0)/1000) * 1.0 * 4439 * 1.25</td>
</tr>
<tr>
<td>= 107.6 kWh</td>
</tr>
</tbody>
</table>

**HEATING PENALTY**

If electrically heated building:

\[
\Delta kW_{\text{heatpenalty}}^{618} = \frac{((\text{WattsBase}-\text{WattsEE})/1000) \times \text{ISR} \times \text{Hours} \times -\text{IFkWh}}{}
\]

Where:

- **IFkWh** = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

<table>
<thead>
<tr>
<th>For example, delamping a 4 ft T8 fixture in a heat pump heated office building:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔkW_{\text{heatpenalty}} =((19.4 - 0)/1000) * 1.0 * 4439 * -0.151</td>
</tr>
<tr>
<td>= -13.0 kWh</td>
</tr>
</tbody>
</table>

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \frac{((\text{WattsBase}-\text{WattsEE})/1000) \times \text{ISR} \times \text{WHFd} \times \text{CF}}{}
\]

Where:

- **WHFd** = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

| CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value. |

Other factors as defined above

<table>
<thead>
<tr>
<th>For example, delamping a 4 ft T8 fixture in an office building:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔkW =((19.4 - 0)/1000) * 1.0 * 1.3 * 0.66</td>
</tr>
<tr>
<td>= 0.017 kW</td>
</tr>
</tbody>
</table>

\(^{618}\text{Negative value because this is an increase in heating consumption due to the efficient lighting.}\)
**Natural Gas Energy Savings**

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

\[
\Delta \text{Therms} = \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{ISR} \times \text{Hours} \times \text{IFTherms}
\]

Where:

- \(\text{IFTherms}\) = Lighting-HVAC Interaction Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

For example, delamping a 4 ft T8 fixture in an office building:

\[
\Delta \text{Therms} = \frac{(19.4 - 0)}{1000} \times 1.0 \times 4439 \times -0.016 = -1.4 \text{ therms}
\]

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code:** CI-LTG-DLMP-V02-140601

**Review Deadline:** 1/1/2021

---

\(^{619}\) Negative value because this is an increase in heating consumption due to the efficient lighting.
4.5.3 High Performance and Reduced Wattage T8 Fixtures and Lamps

DESCRIPTION

This measure applies to “High Performance T8” (HPT8) lamp/ballast systems that have higher lumens per watt than standard T8 systems. This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures. Retrofit measures may include new fixtures or relamp/reballast measures. In addition, options have been provided to allow for the “Reduced Wattage T8 lamps” or RWT8 lamps that result in relamping opportunities that produce equal or greater light levels than standard T8 lamps while using fewer watts.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 99% Commercial and 1% Residential should be used.

This measure was developed to be applicable to the following program types: TOS, RF, DI.

If applied to other program types, the measure savings should be verified.

The measure applies to all commercial HPT8 installations excluding new construction and major renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for the different types of installations. Whenever possible, actual costs and hours of use should be utilized for savings calculations. Default new and baseline assumptions have been provided in the reference tables. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. HPT8 configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs.

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and Direct Install (DI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This measure relates to the installation of new equipment with efficiency that exceeds that of equipment that would have been installed following standard market practices. In general, the measure will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. High-bay applications use this system paired with qualifying high ballast factor ballasts and high performance 32 w lamps. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms.</td>
<td></td>
</tr>
<tr>
<td>This measure relates to the replacement of existing equipment with new equipment with efficiency that exceeds that of the existing equipment. In general, the retrofit will include qualifying high efficiency low ballast factor ballasts paired with high efficiency long life lamps as detailed in the attached tables. Custom lighting designs can use qualifying low, normal or high ballast factor ballasts and qualifying lamps in lumen equivalent applications where total system wattage is reduced when calculated using the Calculation of Savings Algorithms. High efficiency troffers (new/or retrofit) utilizing HPT8 technology can provide even greater savings. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID high-bay fixtures, while using fewer watts; these systems typically utilize high ballast factor ballasts, but qualifying low and normal ballast factor ballasts may be used when appropriate light levels are provided and overall wattage is reduced.</td>
<td></td>
</tr>
</tbody>
</table>

620 Based on weighted average of Final ComEd’s BILD program data from PY5 and PY6. For Residential installations, hours of use assumptions from ‘5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture’ measure should be used.
DEFINITION OF EFFICIENT EQUIPMENT

The efficient conditions for all applications are a qualifying HP or RWT8 fixture and lamp/ballast combinations listed on the CEE website under qualifying HP T8 products\(^{621}\) and qualifying RWT8 products\(^{622}\).

The definition of efficient equipment varies based on the program and is defined below:

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and Direct Install (DI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High efficiency troffers combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts. High bay fixtures must have fixture efficiencies of 85% or greater. RWT8 lamps: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table. This measure assumes a lamp only purchase.</td>
<td>High efficiency troffers (new or retrofit kits) combined with high efficiency lamps and ballasts allow for fewer lamps to be used to provide a given lumen output. High efficiency troffers must have a fixture efficiency of 80% or greater to qualify. Default values are given for a 2 lamp HPT8 fixture replacing a 3 lamp standard efficiency T8 fixture, but other configurations may qualify and the Calculation of savings algorithm used to account for base watts being replaced with EE watts. High bay fixtures will have fixture efficiencies of 85% or greater. RWT8: 2', 3' and 8' lamps must meet the wattage requirements specified in the RWT8 new and baseline assumptions table.</td>
</tr>
</tbody>
</table>

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment varies based on the program and is defined below:

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and Direct Install (DI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The baseline is the existing system. The baseline is standard efficiency T8 systems that would have been installed. The baseline for high-bay fixtures is pulse start metal halide fixtures, the baseline for a 2 lamp high efficiency troffer is a 3 lamp standard efficiency troffer.</td>
<td>The baseline is the existing system. In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v6.0 until 1/1/2019 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 2019. See table C-1.</td>
</tr>
</tbody>
</table>

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of efficient equipment varies based on the program and is defined below:

---

\(^{621}\) [http://library.cee1.org/content/cee-high-performance-t8-specification](http://library.cee1.org/content/cee-high-performance-t8-specification)

\(^{622}\) [http://library.cee1.org/content/reduced-wattage-t8-specification](http://library.cee1.org/content/reduced-wattage-t8-specification)
**Time of Sale (TOS)**

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and Direct Install (DI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixture lifetime is 15 years. Fixtures which utilize RWT8 lamps have a lifetime equivalent to the life of the lamp, capped at 15 years. There is no guarantee that a reduced wattage lamp will be installed at time of burnout, but if one is, savings will be captured in the RWT8 measure below. RWT8 lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table &quot;RWT8 Component Costs and Lifetime&quot;), capped at 15 years.623</td>
<td>Fixture lifetime is 15 years. As per explanation above, for existing T12 fixtures, a mid life baseline shift should be applied in 2019 as described in table C-1. Note, since the fixture lifetime is deemed at 15 years, the replacement cost of both the lamp and ballast should be incorporated into the O&amp;M calculation.</td>
</tr>
</tbody>
</table>

**DEEMED MEASURE COST**

The deemed measure cost is found in the reference table at the end of this characterization.

**LOADSHAPE**

- Loadshape C06 - Commercial Indoor Lighting
- Loadshape C07 - Grocery/Conv. Store Indoor Lighting
- Loadshape C08 - Hospital Indoor Lighting
- Loadshape C09 - Office Indoor Lighting
- Loadshape C10 - Restaurant Indoor Lighting
- Loadshape C11 - Retail Indoor Lighting
- Loadshape C12 - Warehouse Indoor Lighting
- Loadshape C13 - K-12 School Indoor Lighting
- Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
- Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
- Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
- Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
- Loadshape C18 - Industrial Indoor Lighting
- Loadshape C19 - Industrial Outdoor Lighting
- Loadshape C20 - Commercial Outdoor Lighting

---

623 15 years from GDS Measure Life Report, June 2007
624 Ibid
Algorithm

Calculation of Savings

Electric Energy Savings

\[ \Delta \text{kWh} = \left( \frac{\text{Watts}_{\text{base}} - \text{Watts}_{\text{EE}}}{1000} \right) \times \text{Hours} \times \text{WHF}_{e} \times \text{ISR} \]

Where:

- \( \text{Watts}_{\text{base}} \) = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, or a custom value can be entered if the configurations in the tables is not representative of the existing system.

<table>
<thead>
<tr>
<th>Program</th>
<th>Reference Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>A-1: HPT8 New and Baseline Assumptions</td>
</tr>
<tr>
<td>Retrofit</td>
<td>A-2: HPT8 New and Baseline Assumptions</td>
</tr>
<tr>
<td>Reduced Wattage T8, time of sale or retrofit</td>
<td>A-3: RWT8 New and Baseline Assumptions</td>
</tr>
</tbody>
</table>

- \( \text{Watts}_{\text{EE}} \) = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, or a custom value can be entered if the configurations in the tables is not representative of the existing system.

<table>
<thead>
<tr>
<th>Program</th>
<th>Reference Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>A-1: HPT8 New and Baseline Assumptions</td>
</tr>
<tr>
<td>Retrofit</td>
<td>A-2: HPT8 New and Baseline Assumptions</td>
</tr>
<tr>
<td>Reduced Wattage T8, time of sale or retrofit</td>
<td>A-3: RWT8 New and Baseline Assumptions</td>
</tr>
</tbody>
</table>

- Hours = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours. If hours or building type are unknown, use the Miscellaneous value.

- WHF\(_e\) = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

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

\[ \text{ISR} = 100\%^{625} \]

If application form completed with sign off that equipment is not placed into storage

625 Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an “In-Service Rate” when commercial customers complete an application form.
### Heating Penalty

If electrically heated building:

\[ \Delta k\text{Wh}_{\text{heat penalty}} = \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{ISR} \times \text{Hours} \times \text{IFkWh} \]

Where:

- \( \text{IFkWh} \) = Lighting-HVAC Interaction Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

### Summer Coincident Demand Savings

\[ \Delta k\text{W} = \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{WHF}_d \times \text{CF} \times \text{ISR} \]

Where:

- \( \text{WHF}_d \) = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled \( \text{WHF}_d \) is 1.
- \( \text{CF} \) = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

### Natural Gas Savings

\[ \Delta \text{Therms} = \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{ISR} \times \text{Hours} \times \text{IFTherms} \]

Where:

- \( \text{IFTherms} \) = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 4.5 for each building type.

---

626 1st year in service rate is based upon review of PY5-6 evaluations from ComEd’s commercial lighting program (BILD) (see ‘IL Commercial Lighting ISR_2014.xls’ for more information

627 The 98% Lifetime ISR assumption is based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report; Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact

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

629 Negative value because this is an increase in heating consumption due to the efficient lighting.
WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

Actual operation and maintenance costs will vary by specific equipment installed/replaced. See Reference tables for Operating and Maintenance Values;

<table>
<thead>
<tr>
<th>Program</th>
<th>Reference Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>B-1: HPT8 Component Costs and Lifetime</td>
</tr>
<tr>
<td>Retrofit</td>
<td>B-2: HPT8 Component Costs and Lifetime</td>
</tr>
<tr>
<td>Reduced Wattage T8, time of sale or retrofit</td>
<td>B-3: HPT8 Component Costs and Lifetime</td>
</tr>
</tbody>
</table>

REFERENCE TABLES

See following page
A-1: Time of Sale: HPT8 New and Baseline Assumptions

<table>
<thead>
<tr>
<th>EE Measure Description</th>
<th>Nominal Watts</th>
<th>WattSEE</th>
<th>Baseline Description</th>
<th>Nominal Watt</th>
<th>WattsBASE</th>
<th>Incremental Cost</th>
<th>WattsSAVE</th>
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<td>4-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>128</td>
<td>147.2</td>
<td>200 Watt Pulse Start Metal-Halide</td>
<td>200</td>
<td>232</td>
<td>$75</td>
<td>84.80</td>
</tr>
<tr>
<td>4-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>128</td>
<td>147.2</td>
<td>250 Watt Metal Halide</td>
<td>250</td>
<td>295</td>
<td>$75</td>
<td>147.80</td>
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<tr>
<td>6-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>192</td>
<td>220.8</td>
<td>320 Watt Pulse Start Metal Halide</td>
<td>320</td>
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<td>$75</td>
<td>128.00</td>
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<td>6-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>192</td>
<td>220.8</td>
<td>400 Watt Pulse Start Metal Halide</td>
<td>400</td>
<td>455</td>
<td>$75</td>
<td>234.20</td>
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<td>8-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>256</td>
<td>294.4</td>
<td>Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH</td>
<td>320</td>
<td>476</td>
<td>$75</td>
<td>181.60</td>
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<td>292.4</td>
<td>Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide</td>
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<td>618</td>
<td>75</td>
<td>323.60</td>
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<tr>
<td>1-Lamp HPT8-high performance 32 w lamp</td>
<td>32</td>
<td>24.64</td>
<td>1-Lamp Standard F32T8 w/ Elec. Ballast</td>
<td>32</td>
<td>28.16</td>
<td>$15</td>
<td>3.52</td>
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<td>2-Lamp HPT8-high performance 32 w lamp</td>
<td>64</td>
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<td>2-Lamp Standard F32T8 w/ Elec. Ballast</td>
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<td>56.32</td>
<td>$18</td>
<td>7.04</td>
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<td>2-Lamp HPT8-high performance 28 w lamp</td>
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<td>2-Lamp HPT8-high performance 25 w lamp</td>
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<td>2-Lamp Standard F32T8 w/ Elec. Ballast</td>
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<td>$18</td>
<td>17.82</td>
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<td>3-Lamp HPT8-high performance 32 w lamp</td>
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<td>73.92</td>
<td>3-Lamp Standard F32T8 w/ Elec. Ballast</td>
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<td>$20</td>
<td>10.56</td>
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<td>3-Lamp HPT8-high performance 28 w lamp</td>
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<td>64.68</td>
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<td>57.75</td>
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<td>84.48</td>
<td>$20</td>
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<tr>
<td>4-Lamp HPT8-high performance 32 w lamp</td>
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<td>98.56</td>
<td>4-Lamp Standard F32T8 w/ Elec. Ballast</td>
<td>128</td>
<td>112.64</td>
<td>$23</td>
<td>14.08</td>
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<td>4-Lamp HPT8-high performance 28 w lamp</td>
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<td>86.24</td>
<td>4-Lamp Standard F32T8 w/ Elec. Ballast</td>
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<td>$23</td>
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<td>4-Lamp HPT8-high performance 25 w lamp</td>
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<td>77</td>
<td>4-Lamp Standard F32T8 w/ Elec. Ballast</td>
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<td>35.64</td>
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<td>2-lamp High-Performance HPT8 Troffer</td>
<td>64</td>
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<td>3-Lamp F32T8 w/ Elec. Ballast</td>
<td>96</td>
<td>84.48</td>
<td>$100</td>
<td>35.20</td>
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Table developed using a constant ballast factor of .77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy.

---

630 Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.
### A-2: Retrofit HPT8 New and Baseline Assumptions

<table>
<thead>
<tr>
<th>EE Measure Description</th>
<th>Nominal Watts</th>
<th>Ballast Factor</th>
<th>WattsEE</th>
<th>Baseline Description</th>
<th>Nominal Watts</th>
<th>WattsBASE</th>
<th>WattsSAVE</th>
<th>Full Measure Cost</th>
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<td>4-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
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<td>1.15</td>
<td>147.2</td>
<td>200 Watt Pulse Start Metal-Halide</td>
<td>200</td>
<td>232</td>
<td>84.80</td>
<td>$200</td>
</tr>
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<td>4-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
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<td>1.15</td>
<td>147.2</td>
<td>250 Watt Metal Halide</td>
<td>250</td>
<td>295</td>
<td>147.80</td>
<td>$200</td>
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<tr>
<td>6-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>192</td>
<td>1.15</td>
<td>220.8</td>
<td>320 Watt Pulse Start Metal-Halide</td>
<td>320</td>
<td>348.8</td>
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<td>220.8</td>
<td>400 Watt Pulse Start Metal-Halide</td>
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<td>234.20</td>
<td>$225</td>
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<td>8-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>256</td>
<td>1.15</td>
<td>294.4</td>
<td>Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH</td>
<td>320</td>
<td>476</td>
<td>181.60</td>
<td>$250</td>
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<tr>
<td>8-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
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<td>1.15</td>
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<td>Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 400 W Metal Halide</td>
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<td>1-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>0.77</td>
<td>24.64</td>
<td>1-Lamp F34T12 w/ EEMag Ballast</td>
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<td>42</td>
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<td>$50</td>
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<td>2-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>49.28</td>
<td>2-Lamp F34T12 w/ EEMag Ballast</td>
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<td>67</td>
<td>17.72</td>
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<tr>
<td>3-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>73.92</td>
<td>3-Lamp F34T12 w/ EEMag Ballast</td>
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<td>104</td>
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<td>4-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>98.56</td>
<td>4-Lamp F34T12 w/ EEMag Ballast</td>
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<td>144</td>
<td>45.44</td>
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<td>1-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>24.64</td>
<td>1-Lamp F40T12 w/ EEMag Ballast</td>
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<td>2-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>0.77</td>
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<td>2-Lamp F40T12 w/ EEMag Ballast</td>
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<td>37.72</td>
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<td>3-Lamp Relamp/Reballast T12 to HPT8</td>
<td>96</td>
<td>0.77</td>
<td>73.92</td>
<td>3-Lamp F40T12 w/ EEMag Ballast</td>
<td>120</td>
<td>141</td>
<td>67.08</td>
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<td>4-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>0.77</td>
<td>98.56</td>
<td>4-Lamp F40T12 w/ EEMag Ballast</td>
<td>160</td>
<td>172</td>
<td>73.44</td>
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<tr>
<td>1-Lamp Relamp/Reballast T12 to HPT8</td>
<td>32</td>
<td>0.77</td>
<td>24.64</td>
<td>1-Lamp F40T12 w/ Mag Ballast</td>
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<td>51</td>
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<td>$50</td>
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<td>2-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>0.77</td>
<td>49.28</td>
<td>2-Lamp F40T12 w/ Mag Ballast</td>
<td>80</td>
<td>97</td>
<td>47.72</td>
<td>$55</td>
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<td>3-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>0.77</td>
<td>73.92</td>
<td>3-Lamp F40T12 w/ Mag Ballast</td>
<td>120</td>
<td>135</td>
<td>61.08</td>
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<td>4-Lamp Relamp/Reballast T12 to HPT8</td>
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<td>0.77</td>
<td>98.56</td>
<td>4-Lamp F40T12 w/ Mag Ballast</td>
<td>160</td>
<td>175</td>
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<td>1-Lamp Relamp/Reballast T8 to HPT8</td>
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<td>0.77</td>
<td>24.64</td>
<td>1-Lamp F32T8 w/ Elec. Ballast</td>
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<td>28.16</td>
<td>3.52</td>
<td>$50</td>
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<td>2-Lamp Relamp/Reballast T8 to HPT8</td>
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<td>0.77</td>
<td>49.28</td>
<td>2-Lamp F32T8 w/ Elec. Ballast</td>
<td>64</td>
<td>56.32</td>
<td>7.04</td>
<td>$55</td>
</tr>
<tr>
<td>3-Lamp Relamp/Reballast T8 to HPT8</td>
<td>96</td>
<td>0.77</td>
<td>73.92</td>
<td>3-Lamp F32T8 w/ Elec. Ballast</td>
<td>96</td>
<td>84.48</td>
<td>10.56</td>
<td>$60</td>
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<tr>
<td>4-Lamp Relamp/Reballast T8 to HPT8</td>
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<td>0.77</td>
<td>98.56</td>
<td>4-Lamp F32T8 w/ Elec. Ballast</td>
<td>128</td>
<td>112.64</td>
<td>14.08</td>
<td>$65</td>
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### EE Measure Description

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<th>EE Measure Description</th>
<th>Nominal Watts</th>
<th>Ballast Factor</th>
<th>WattsEE</th>
<th>Baseline Description</th>
<th>Nominal Watts</th>
<th>WattsBASE</th>
<th>WattsSAVE</th>
<th>Full Measure Cost</th>
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<tr>
<td>2-lamp High-Performance HPT8 Troffer or high efficiency retrofit troffer</td>
<td>64</td>
<td>0.77</td>
<td>49.28</td>
<td>3-Lamp F32T8 w/ Elec. Ballast</td>
<td>96</td>
<td>84.48</td>
<td>35.20</td>
<td>$100</td>
</tr>
</tbody>
</table>

Table developed using a constant ballast factor of 0.77 for troffers/linear HPT8 and 1.15 for HPT8 highbay, 1.0 for all MH/MHPS, and 0.95 for T12 and 0.88 for standard T8. Input wattages are an average of manufacturer inputs that account for ballast efficacy.

**A– 3: RWT8 New and Baseline Assumptions**

Table developed using a constant ballast factor of 0.88 for RWT8 and Standard T8.

<table>
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<tr>
<th>EE Measure Description</th>
<th>Nominal Watts</th>
<th>Wattsee</th>
<th>EE Lamp Cost</th>
<th>Baseline Description</th>
<th>Base Lamp Cost</th>
<th>Nominal Watts</th>
<th>WattsBASE</th>
<th>WattsSAVE</th>
<th>Measure Cost</th>
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<td>$4.50</td>
<td>F32 T8 Standard Lamp</td>
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<td>32</td>
<td>28.16</td>
<td>3.52</td>
<td>$2.00</td>
</tr>
<tr>
<td>RWT8 F2T8 Extra Life Lamp</td>
<td>28</td>
<td>24.64</td>
<td>$4.50</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>32</td>
<td>28.16</td>
<td>3.52</td>
<td>$2.00</td>
</tr>
<tr>
<td>RWT8 - F32/25W T8 Lamp</td>
<td>25</td>
<td>22.00</td>
<td>$4.50</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>32</td>
<td>28.16</td>
<td>6.16</td>
<td>$2.00</td>
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<tr>
<td>RWT8 - F32/25W T8 Lamp Extra Life</td>
<td>25</td>
<td>22.00</td>
<td>$4.50</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>32</td>
<td>28.16</td>
<td>6.16</td>
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<td>RWT8 F17T8 Lamp - 2 ft</td>
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<td>14.08</td>
<td>$4.80</td>
<td>F17 T8 Standard Lamp - 2ft</td>
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<td>14.96</td>
<td>0.88</td>
<td>$2.00</td>
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<td>RWT8 F25T8 Lamp - 3 ft</td>
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<td>20.24</td>
<td>$5.10</td>
<td>F25 T8 Standard Lamp - 3ft</td>
<td>$3.10</td>
<td>25</td>
<td>22.00</td>
<td>1.76</td>
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<td>RWT8 F30T8 Lamp - 6' Utube</td>
<td>30</td>
<td>26.40</td>
<td>$11.31</td>
<td>F32 T8 Standard Utube</td>
<td>$9.31</td>
<td>32</td>
<td>28.16</td>
<td>1.76</td>
<td>$2.00</td>
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<tr>
<td>RWT8 F29T8 Lamp - Utube</td>
<td>29</td>
<td>25.52</td>
<td>$11.31</td>
<td>F32 T8 Standard Utube</td>
<td>$9.31</td>
<td>32</td>
<td>28.16</td>
<td>2.64</td>
<td>$2.00</td>
</tr>
<tr>
<td>RWT8 F96T8 Lamp - 8 ft</td>
<td>65</td>
<td>57.20</td>
<td>$9.00</td>
<td>F96 T8 Standard Lamp - 8 ft</td>
<td>$7.00</td>
<td>70</td>
<td>61.60</td>
<td>4.40</td>
<td>$2.00</td>
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### B-1: Time of Sale T8 Component Costs and Lifetime

<table>
<thead>
<tr>
<th>EE Measure Description</th>
<th>EE Lamp Cost (hrs)</th>
<th>EE Lamp Life (hrs)</th>
<th>EE Lamp Rep. Cost per lamp</th>
<th>EE Ballast Cost (hrs)</th>
<th>EE Ballast Rep. Cost</th>
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<tbody>
<tr>
<td>4-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>$5.00</td>
<td>24000</td>
<td>$6.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>6-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>$5.00</td>
<td>24000</td>
<td>$6.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>8-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>$5.00</td>
<td>24000</td>
<td>$6.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>1-Lamp HPT8 – all qualifying lamps</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>2-Lamp HPT8 – all qualifying lamps</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>3-Lamp HPT8 – all qualifying lamps</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>4-Lamp HPT8 – all qualifying lamps</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>70000</td>
<td>$15.00</td>
</tr>
</tbody>
</table>

632 Watt, lumen, lamp life, and ballast factor assumptions for efficient measures are based upon Consortium for Energy Efficiency (CEE) Commercial Lighting Qualifying Product Lists. Watt, lumen, lamp life, and ballast factor assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.
### B-2: T8 Retrofit Component Costs and Lifetime\(^{633}\)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
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<td>$5.00</td>
<td>24000</td>
<td>$6.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>200 Watt Pulse Start Metal-Halide</td>
<td>$29.00</td>
<td>12000</td>
<td>$6.67</td>
<td>$87.75</td>
<td>40000</td>
<td>$22.50</td>
</tr>
<tr>
<td>6-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>$5.00</td>
<td>24000</td>
<td>$6.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>320 Watt Pulse Start Metal-Halide</td>
<td>$72.00</td>
<td>20000</td>
<td>$6.67</td>
<td>$109.35</td>
<td>40000</td>
<td>$22.50</td>
</tr>
<tr>
<td>8-Lamp HPT8 w/ High-BF Ballast High-Bay</td>
<td>$5.00</td>
<td>24000</td>
<td>$6.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>Proportionally Adjusted according to 6-Lamp HPT8 Equivalent to 320 PSMH</td>
<td>$17.00</td>
<td>20000</td>
<td>$6.67</td>
<td>$109.35</td>
<td>40000</td>
<td>$22.50</td>
</tr>
<tr>
<td>1-Lamp Relamp/Reballast T12 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>1-Lamp F34T12 w/ EEMag Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>40000</td>
<td>$15.00</td>
</tr>
<tr>
<td>2-Lamp Relamp/Reballast T12 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>2-Lamp F34T12 w/ EEMag Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>40000</td>
<td>$15.00</td>
</tr>
<tr>
<td>3-Lamp Relamp/Reballast T12 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>3-Lamp F34T12 w/ EEMag Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>40000</td>
<td>$15.00</td>
</tr>
<tr>
<td>4-Lamp Relamp/Reballast T12 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>4-Lamp F34T12 w/ EEMag Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>40000</td>
<td>$15.00</td>
</tr>
<tr>
<td>1-Lamp Relamp/Reballast T8 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>1-Lamp F32T8 w/ Elec. Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>2-Lamp Relamp/Reballast T8 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>2-Lamp F32T8 w/ Elec. Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>70000</td>
<td>$15.00</td>
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<tr>
<td>3-Lamp Relamp/Reballast T8 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>3-Lamp F32T8 w/ Elec. Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
<td>70000</td>
<td>$15.00</td>
</tr>
<tr>
<td>4-Lamp Relamp/Reballast T8 to HPT8</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>4-Lamp F32T8 w/ Elec. Ballast</td>
<td>$2.70</td>
<td>20000</td>
<td>$2.67</td>
<td>$20.00</td>
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<td>2-Lamp High-Performance HPT8 Troffer</td>
<td>$5.00</td>
<td>24000</td>
<td>$2.67</td>
<td>$32.50</td>
<td>70000</td>
<td>$15.00</td>
<td>3-Lamp F32T8 w/ Elec. Ballast</td>
<td>$2.50</td>
<td>20000</td>
<td>$2.67</td>
<td>$15.00</td>
<td>70000</td>
<td>$15.00</td>
</tr>
</tbody>
</table>

\(^{633}\) Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.
### B-3: Reduced Wattage T8 Component Costs and Lifetime

<table>
<thead>
<tr>
<th>EE measure description</th>
<th>EE Lamp Cost</th>
<th>EE Lamp Life (hrs)</th>
<th>Baseline Description</th>
<th>Base Lamp Cost</th>
<th>Base Lamp Life (hrs)</th>
<th>Base Lamp Rep. Labor Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>RW T8 - F28T8 Lamp</td>
<td>$4.50</td>
<td>30000</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 F2T8 Extra Life Lamp</td>
<td>$4.50</td>
<td>36000</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 - F32/25W T8 Lamp</td>
<td>$4.50</td>
<td>30000</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 - F32/25W T8 Lamp Extra Life</td>
<td>$4.50</td>
<td>36000</td>
<td>F32 T8 Standard Lamp</td>
<td>$2.50</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 F17T8 Lamp - 2 ft</td>
<td>$4.80</td>
<td>18000</td>
<td>F17 T8 Standard Lamp - 2ft</td>
<td>$2.80</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 F25T8 Lamp - 3 ft</td>
<td>$5.10</td>
<td>18000</td>
<td>F25 T8 Standard Lamp - 3ft</td>
<td>$3.10</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 F30T8 Lamp - 6' Utube</td>
<td>$11.31</td>
<td>24000</td>
<td>F32 T8 Standard Utube</td>
<td>$9.31</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 F29T8 Lamp - Utube</td>
<td>$11.31</td>
<td>24000</td>
<td>F32 T8 Standard Utube</td>
<td>$9.31</td>
<td>15000</td>
<td>$2.67</td>
</tr>
<tr>
<td>RWT8 F96T8 Lamp - 8 ft</td>
<td>$9.00</td>
<td>24000</td>
<td>F96 T8 Standard Lamp - 8 ft</td>
<td>$7.00</td>
<td>15000</td>
<td>$2.67</td>
</tr>
</tbody>
</table>

---

634 Cost assumptions for baseline fixtures are based upon manufacturer specification sheets. Baseline and efficient measure cost data comes from lighting suppliers, past Efficiency Vermont projects, and professional judgment.
C-1: T12 Baseline Adjustment:

For measures installed up to 1/1/2019, the full savings (as calculated above in the Algorithm section) will be claimed up to 1/1/2019. A savings adjustment will be applied to the annual savings for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table below.

Savings Adjustment Factors

<table>
<thead>
<tr>
<th>EE Measure Description</th>
<th>Savings Adjustment T12 EE mag ballast and 34 w lamps to HPT8</th>
<th>Savings Adjustment T12 EE mag ballast and 40 w lamps to HPT8</th>
<th>Savings Adjustment T12 mag ballast and 40 w lamps to HPT8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Lamp Relamp/Reballast T12 to HPT8</td>
<td>47%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>2-Lamp Relamp/Reballast T12 to HPT8</td>
<td>53%</td>
<td>30%</td>
<td>22%</td>
</tr>
<tr>
<td>3-Lamp Relamp/Reballast T12 to HPT8</td>
<td>42%</td>
<td>38%</td>
<td>21%</td>
</tr>
<tr>
<td>4-Lamp Relamp/Reballast T12 to HPT8</td>
<td>44%</td>
<td>29%</td>
<td>23%</td>
</tr>
</tbody>
</table>

Measures installed in 2018 will claim full savings for one year. Savings adjustment factors will be applied to the full savings for savings starting in 1/1/2019 and for the remainder of the measure life. The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 and wattage reduction from T12 EE ballast with 40 w lamp baseline from the table ‘T8 New and Baseline Assumptions’.535

Example: 2 lamp T8 to 2 lamp HPT8 retrofit saves 10 watts, while the T12 EE with 40 w lamp to HPT8 saves 33 watts. Thus the ratio of wattage reduced is 30%.

**MEASURE CODE: CI-LTG-T8FX-V06-160601**

**REVIEW DEADLINE: 1/1/2019**
4.5.4 LED Bulbs and Fixtures

DESCRIPTION

This characterization provides savings assumptions for a variety of LED lamps including Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Torpedoes) and Directional (PAR Lamps, Reflectors, MR16), and fixtures including refrigerated case, recessed and outdoor/garage fixtures.

If the implementation strategy does not allow for the installation location to be known, for Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used, and for Commercial targeted programs a deemed split of 96% Commercial and 4% Residential should be used.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf).

Lamps and fixtures should be found in the reference tables below. Fixtures must be ENERGY STAR labeled or on the Design Lights Consortium qualifying fixture list.

DEFINITION OF BASELINE EQUIPMENT

Refer to the baseline tables. In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) required all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table “LED component Costs and Lifetime.” The analysis period is the same as the lifetime, capped at 15 years. (15 years from GDS Measure Life Report, June 2007).

DEEMED MEASURE COST

Wherever possible, actual incremental costs should be used. Refer to reference table “LED component Cost & Lifetime” for defaults.

LOADSHAPE

| Loadshape C06 | Commercial Indoor Lighting |
| Loadshape C07 | Grocery/Conv. Store Indoor Lighting |
| Loadshape C08 | Hospital Indoor Lighting |
| Loadshape C09 | Office Indoor Lighting |
| Loadshape C10 | Restaurant Indoor Lighting |

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636 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See ‘RESvCI Split_112016.xls’.

637 Based on final ComEd’s BILD program data from PY4,PY5 and PY6. For Residential installations, hours of use assumptions from ‘5.5.6 LED Downlights’ should be used for LED fixtures and ‘5.5.8 LED Screw Based Omnidirectional Bulbs’ should be used for LED bulbs.
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = \left( (\text{Watts}_{\text{base}} - \text{Watts}_{\text{EE}}) / 1000 \right) \times \text{Hours} \times \text{WHF} \times \text{ISR} \]

Where:

- \( \text{Watts}_{\text{base}} \) = Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.
- \( \text{Watts}_{\text{EE}} \) = Actual wattage of LED purchased / installed. If unknown, use default provided below:

For ENERGY STAR rated lamps the following lumen equivalence tables should be used:

**Omnidirectional Lamps - ENERGY STAR Minimum Luminous Efficacy = 80Lm/W for <90 CRI lamps and 70Lm/W for >=90 CRI lamps.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5280</td>
<td>6209</td>
<td>5745</td>
<td>72.9</td>
<td>300.0</td>
<td>227.1</td>
<td>300.0</td>
<td>227.1</td>
</tr>
<tr>
<td>3000</td>
<td>5279</td>
<td>4140</td>
<td>52.5</td>
<td>200.0</td>
<td>147.5</td>
<td>200.0</td>
<td>147.5</td>
</tr>
<tr>
<td>2601</td>
<td>2999</td>
<td>2800</td>
<td>35.5</td>
<td>150.0</td>
<td>114.5</td>
<td>150.0</td>
<td>114.5</td>
</tr>
</tbody>
</table>

\(^{638}\) Based on ENERGY STAR V2.0 specs – for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90 CRI: 70 lm/W. To weight these two criteria, the ENERGY STAR qualified list was reviewed and found to contain 87.8% lamps <90CRI and 12.2% >=90CRI.

\(^{639}\) Calculated as 45lm/W for all EISA non-exempt bulbs.
### LED Bulbs and Fixtures

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1490</td>
<td>2600</td>
<td>2045</td>
<td>26.0</td>
<td>72.0</td>
<td>46.0</td>
<td>45.4</td>
<td>19.5</td>
</tr>
<tr>
<td>1050</td>
<td>1489</td>
<td>1270</td>
<td>16.1</td>
<td>53.0</td>
<td>36.9</td>
<td>28.2</td>
<td>12.1</td>
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<tr>
<td>750</td>
<td>1049</td>
<td>900</td>
<td>11.4</td>
<td>43.0</td>
<td>31.6</td>
<td>20.0</td>
<td>8.6</td>
</tr>
<tr>
<td>310</td>
<td>749</td>
<td>530</td>
<td>6.7</td>
<td>29.0</td>
<td>22.3</td>
<td>11.8</td>
<td>5.0</td>
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<tr>
<td>250</td>
<td>309</td>
<td>280</td>
<td>3.5</td>
<td>25.0</td>
<td>21.5</td>
<td>25.0</td>
<td>21.5</td>
</tr>
</tbody>
</table>

#### Decorative Lamps - ENERGY STAR Minimum Luminous Efficacy = 65 Lm/W for all lamps

<table>
<thead>
<tr>
<th>Nominal wattage of lamp to be replaced (Watts(_{\text{base}}))</th>
<th>Minimum initial light output of LED lamp (lumens)</th>
<th>LED Wattage (Watts(_{\text{EE}}))</th>
<th>Delta Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>70</td>
<td>1.08</td>
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<td>15</td>
<td>90</td>
<td>1.38</td>
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<tr>
<td>25</td>
<td>150</td>
<td>2.31</td>
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<tr>
<td>40</td>
<td>300</td>
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</tr>
<tr>
<td>60</td>
<td>500</td>
<td>7.69</td>
<td>52.3</td>
</tr>
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</table>

#### Directional Lamps - ENERGY STAR Minimum Luminous Efficacy = 70 Lm/W for <90 CRI lamps and 61 Lm/W for >=90 CRI lamps.

For Directional R, BR, and ER lamp types:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Watts(_{\text{base}})</th>
<th>Lumens used to calculate LED Wattage (midpoint)</th>
<th>LED Wattage (Watts(_{\text{EE}}))</th>
<th>Delta Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25” (*see exceptions below)</td>
<td>420</td>
<td>472</td>
<td>40</td>
<td>446</td>
<td>6.6</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td>473</td>
<td>524</td>
<td>45</td>
<td>499</td>
<td>7.3</td>
<td>37.7</td>
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<tr>
<td></td>
<td>525</td>
<td>714</td>
<td>50</td>
<td>620</td>
<td>9.1</td>
<td>40.9</td>
</tr>
<tr>
<td></td>
<td>715</td>
<td>937</td>
<td>65</td>
<td>826</td>
<td>12.1</td>
<td>52.9</td>
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<tr>
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<td>90</td>
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<td>3000</td>
<td>4500</td>
<td>200</td>
<td>3750</td>
<td>55.1</td>
<td>144.9</td>
</tr>
<tr>
<td>*R, BR, and ER with medium screw bases w/</td>
<td>400</td>
<td>449</td>
<td>40</td>
<td>425</td>
<td>6.2</td>
<td>33.8</td>
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<td>499</td>
<td>45</td>
<td>475</td>
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<td>38.0</td>
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<td></td>
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<td>649</td>
<td>50</td>
<td>575</td>
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<td></td>
<td>650</td>
<td>1199</td>
<td>65</td>
<td>925</td>
<td>13.6</td>
<td>51.4</td>
</tr>
</tbody>
</table>
### LED Bulbs and Fixtures

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
<th>Lumens used to calculate LED Wattage (midpoint)</th>
<th>LED Wattage (Watts_{EE})</th>
<th>Delta Watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter &lt;=2.25”</td>
<td></td>
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</tr>
<tr>
<td>*ER30, BR30, BR40, or ER40</td>
<td>400</td>
<td>449</td>
<td>40</td>
<td>425</td>
<td>6.2</td>
<td>33.8</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>499</td>
<td>45</td>
<td>475</td>
<td>7.0</td>
<td>38.0</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>649</td>
<td>50</td>
<td>575</td>
<td>8.5</td>
<td>41.5</td>
</tr>
<tr>
<td>*BR30, BR40, or ER40</td>
<td>650</td>
<td>1419</td>
<td>65</td>
<td>1035</td>
<td>15.2</td>
<td>49.8</td>
</tr>
<tr>
<td>*R20</td>
<td>400</td>
<td>449</td>
<td>40</td>
<td>425</td>
<td>6.2</td>
<td>33.8</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>719</td>
<td>45</td>
<td>585</td>
<td>8.6</td>
<td>36.4</td>
</tr>
<tr>
<td>*All reflector lamps below lumen ranges specified above</td>
<td>200</td>
<td>299</td>
<td>20</td>
<td>250</td>
<td>3.7</td>
<td>16.3</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>399</td>
<td>30</td>
<td>350</td>
<td>5.1</td>
<td>24.9</td>
</tr>
</tbody>
</table>

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool. 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.

\[
\text{Watts}_{\text{base}} = 375.1 - 4.355(D) - \sqrt{227,800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D + BA) + 14.69(BA^2) - 16,720 \times \ln(CBCP)}
\]

Where:

- \(D\) = Bulb diameter (e.g. for PAR20 \(D = 20\))
- \(BA\) = Beam angle
- \(CBCP\) = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Permitted Wattages</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>20, 35, 40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>30S</td>
<td>40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>30L</td>
<td>50, 75</td>
</tr>
<tr>
<td>38</td>
<td>40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250</td>
</tr>
</tbody>
</table>

---

640 http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/

641 The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.
Hours = Average hours of use per year are provided in the Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type. If unknown, use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

ISR = In Service Rate - the percentage of units rebated that actually get installed.

=100% if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

<table>
<thead>
<tr>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>95.7%643</td>
<td>1.2%</td>
<td>1.1%</td>
<td>98.0%644</td>
</tr>
</tbody>
</table>

**HEATING PENALTY**

If electrically heated building:

\[
\Delta k\text{Wh}_{\text{heatpenalty}} = \frac{((\text{WattsBase}-\text{WattsEE})/1000) \times \text{ISR} \times \text{Hours} \times \text{IFkWh}}{\text{WattsEE}}
\]

Where:

- \(\text{IFkWh}\) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, For example, a 9W LED lamp, 450 lumens, is installed in a heat pump heated office in 2014 and sign off form provided:

\[
\Delta k\text{Wh}_{\text{heatpenalty}} = \frac{(29-6.7)/1000)\times1.0\times3088\times-0.151}{9600}\]

\[
= - 10.4 \text{ kWh}
\]

---

642 Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an “In-Service Rate” when commercial customers complete an application form.

643 Based on ComEd’s BILD program data from PY5 and PY6, see “IL Commercial Lighting ISR_2014.xls”.

644 In the absence of any data for LEDs specifically it is assumed that the same proportion of bulbs eventually get installed as for CFLS. The 98% CFL assumption is based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact.

645 Negative value because this is an increase in heating consumption due to the efficient lighting.
DEFERRED INSTALLS
As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs:  Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs:  Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

SUMMER COINCIDENT PEAK DEMAND SAVINGS
\[
\Delta kW = \left( \frac{Watts_{\text{Base}} - Watts_{\text{EE}}}{1000} \right) \times ISR \times WHF_d \times CF
\]
Where:

- $WHF_d$ is the Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings. It is provided in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.
- $CF$ is the Summer Peak Coincidence Factor for the measure. It is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

\[
\Delta kW = \left( \frac{29 - 6.7}{1000} \right) \times 1.3 \times 0.66
\]
\[
= 0.019 \text{ kW}
\]

NATURAL GAS ENERGY SAVINGS
Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

\[
\Delta \text{Therms} = \left( \frac{(Watts_{\text{Base}} - Watts_{\text{EE}})}{1000} \right) \times ISR \times Hours \times IFTerms
\]
Where:

- $IFTerms$ is the Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, for example, a 9W LED lamp, 450 lumens, is installed in an office in 2014 and sign off form provided:

\[
\Delta \text{Therms} = \left( \frac{29 - 6.7}{1000} \right) \times 1.0 \times 3088 \times -0.016
\]
\[
= -1.10 \text{ therms}
\]

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A
DEEMED O&M COST ADJUSTMENT CALCULATION

For all measures except Standard Omnidirectional lamps (which have an EISA baseline shift) the individual component lifetimes and costs are provided in the reference table section below.\textsuperscript{646}

In order to account for the falling EISA Qualified bulb replacement cost provided above, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb (assumed to be 15,000/3612 = 4.2 years) is calculated.\textsuperscript{647} The key assumptions used in this calculation are documented below:\textsuperscript{648}

<table>
<thead>
<tr>
<th>Location</th>
<th>Lumen Level</th>
<th>Std Inc.</th>
<th>EISA Compliant</th>
<th>CFL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Halogen</td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>Lumens &lt;310 or &gt;2600 (EISA exempt)</td>
<td>$0.43</td>
<td>$1.25</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$0.43</td>
<td>$1.25</td>
<td>N/A</td>
</tr>
<tr>
<td>Multi Family Common Areas</td>
<td>Lumens &lt;310 or &gt;2600 (non-EISA compliant)</td>
<td>$0.43</td>
<td>$1.25</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$0.43</td>
<td>N/A</td>
<td>$2.45</td>
</tr>
</tbody>
</table>

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR:

<table>
<thead>
<tr>
<th>Location</th>
<th>Lumen Level</th>
<th>NPV of replacement costs for period</th>
<th>Levelized annual replacement cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>Lumens &lt;310 or &gt;2600 (EISA exempt)</td>
<td>$6.02</td>
<td>$6.02</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$13.22</td>
<td>$9.64</td>
</tr>
<tr>
<td>Multi Family Common Areas</td>
<td>Lumens &lt;310 or &gt;2600 (non-EISA compliant)</td>
<td>$5.92</td>
<td>$5.92</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$17.20</td>
<td>$14.25</td>
</tr>
</tbody>
</table>

For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.\textsuperscript{649} The replacement cycle is based on the miscellaneous hours of use. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement and CFLs after 10,000 hours.

REFERENCE TABLES

LED Bulb Assumptions

Wherever possible, actual incremental costs should be used. If unavailable assume the following incremental costs.\textsuperscript{650}

---

\textsuperscript{646} See “LED Lighting Systems TRM Reference Tables” for breakdown of component cost assumptions.

\textsuperscript{647} See C&I OmniDirectional LED O&M Calc_012017.xls” for more information. The values assume the non-residential average hours assumption of 3612.

\textsuperscript{648} Based upon pricing forecast developed by Applied Proactive Technologies Inc (APT) based on industry input and provided to Ameren.

\textsuperscript{649} The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.

\textsuperscript{650} Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. Given LED prices are expected to continue declining assumed costs should be reassessed on an annual basis and replaced with IL specific LED program information when available.
Bulb Type | Year | LED | Incandescent | Incremental Cost
--- | --- | --- | --- | ---
Omnidirectional | 2017 | $3.21 | $1.25 | $1.96
| 2018 | $3.21 | | $1.96
| 2019 | $3.11 | | $1.86
Directional | 2017 | $6.24 | $3.53 | $2.71
| 2018-2019 | $5.18 | | $1.65
Decorative and Globe | 2017 | $3.50 | $1.60 | $1.90
| 2018-2019 | $3.40 | $1.74 | $1.66

Directional and Decorative O&M; apply incandescent cost assumption provided above with a frequency calculated by dividing the assumed rated life of the baseline bulb (1000 hours) by the building specific hours of use assumption

**LED Fixture Wattage and Incremental Cost Assumptions**

| LED Category | EE Measure Description | Watt | Baseline Description | Watt | Incremental Cost | Mid Life Savings Adjustment (2018)
--- | --- | --- | --- | --- | --- | ---
LED Downlight Fixtures | LED Recessed, Surface, Pendant Downlights | 17.6 | Baseline LED Recessed, Surface, Pendant Downlights | 54.3 | $27 | N/A
LED Interior Directional | LED Track Lighting | 12.2 | Baseline LED Track Lighting | 60.4 | $59 | N/A
| LED Wall-Wash Fixtures | 8.3 | Baseline LED Wall-Wash Fixtures | 17.7 | $59 | N/A
LED Display Case | LED Display Case Light Fixture | 7.1 per ft | Baseline LED Display Case Light Fixture | 36.2 per ft | $11/ft | N/A
| LED Undercabinet Shelf-Mounted Task Light Fixtures | 7.1 per ft | Baseline LED Undercabinet Shelf-Mounted Task Light Fixtures | 36.2 per ft | $11/ft | N/A
| LED Refrigerated Case Light, Horizontal or Vertical | 7.6 per ft | Baseline LED Refrigerated Case Light, Horizontal or Vertical (per foot) | 15.2 per ft | $11/ft | N/A
| LED Freezer Case Light, Horizontal or Vertical | 7.7 per ft | Baseline LED Freezer Case Light, Horizontal or Vertical (per foot) | 18.7 per ft | $11/ft | N/A
LED Linear Replacement Lamps | LED 4' Linear Replacement Lamp | 18.7 | 80:20 T12:T8; Lamp Only 32w T8:34w T12 | 33.6 | $24 | 89%
| LED 2' Linear Replacement Lamp | 9.7 | 80:20 T12:T8; Lamp Only 17w T8:20w T12 | 19.4 | $13 | 75%
LED Troffers | LED 2x2 Recessed Light Fixture, 2000-3500 lumens | 34.1 | 80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12 | 61.0 | $48 | 85%
| LED 2x2 Recessed Light Fixture, 3501-5000 lumens | 42.8 | 80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12 | 103.3 | $91 | 69%
| LED 2x4 Recessed Light Fixture, 3000-4500 lumens | 37.9 | 80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12 | 61.0 | $62 | 83%

---
<table>
<thead>
<tr>
<th>LED Category</th>
<th>EE Measure Description</th>
<th>Watts&lt;sub&gt;EE&lt;/sub&gt;</th>
<th>Baseline Description</th>
<th>Watts&lt;sub&gt;BASE&lt;/sub&gt;</th>
<th>Incremental Cost</th>
<th>Mid Life Savings Adjustment (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LED 2x4 Recessed Light Fixtures</strong></td>
<td>4501-6000 lumens</td>
<td>54.3</td>
<td>80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12</td>
<td>103.3</td>
<td>$99</td>
<td>62%</td>
</tr>
<tr>
<td><strong>LED 2x4 Recessed Light Fixtures</strong></td>
<td>6001-7500 lumens</td>
<td>72.7</td>
<td>80:20 T12:Standard T8 4-Lamp 32w T8, 4-Lamp 34w T12</td>
<td>137.7</td>
<td>$150</td>
<td>61%</td>
</tr>
<tr>
<td><strong>LED 1x4 Recessed Light Fixtures</strong></td>
<td>1500-3000 lumens</td>
<td>18.1</td>
<td>80:20 T12:Standard T8 1-Lamp 32w T8, 1-Lamp 34w T12</td>
<td>30.6</td>
<td>$36</td>
<td>88%</td>
</tr>
<tr>
<td><strong>LED 1x4 Recessed Light Fixtures</strong></td>
<td>3001-4500 lumens</td>
<td>39.6</td>
<td>80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12</td>
<td>61.0</td>
<td>$76</td>
<td>81%</td>
</tr>
<tr>
<td><strong>LED 1x4 Recessed Light Fixtures</strong></td>
<td>4501-6000 lumens</td>
<td>53.1</td>
<td>80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12</td>
<td>103.3</td>
<td>$130</td>
<td>62%</td>
</tr>
<tr>
<td><strong>LED Surface &amp; Suspended Linear Fixture, &lt;= 3000 lumens</strong></td>
<td>19.7</td>
<td>80:20 T12:Standard T8 1-Lamp 32w T8, 1-Lamp 34w T12</td>
<td>30.6</td>
<td>$54</td>
<td>86%</td>
<td></td>
</tr>
<tr>
<td><strong>LED Surface &amp; Suspended Linear Fixture, 3001-4500 lumens</strong></td>
<td>37.8</td>
<td>80:20 T12:Standard T8 2-Lamp 32w T8, 2-Lamp 34w T12</td>
<td>61.0</td>
<td>$104</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td><strong>LED Surface &amp; Suspended Linear Fixture, 4501-6000 lumens</strong></td>
<td>55.9</td>
<td>80:20 T12:Standard T8 3-Lamp 32w T8, 3-Lamp 34w T12</td>
<td>103.3</td>
<td>$158</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td><strong>LED Surface &amp; Suspended Linear Fixture, 6001-7500 lumens</strong></td>
<td>62.6</td>
<td>T5HO 2L-F54T5HO - 4'</td>
<td>120.0</td>
<td>$215</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Surface &amp; Suspended Linear Fixture, &gt; 7500 lumens</strong></td>
<td>95.4</td>
<td>T5HO 3L-F54T5HO - 4'</td>
<td>180.0</td>
<td>$374</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Low-Bay Fixtures, &lt;= 10,000 lumens</strong></td>
<td>90.3</td>
<td>3-Lamp T8HO Low-Bay</td>
<td>157.0</td>
<td>$191</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED High-Bay Fixtures, 10,001-15,000 lumens</strong></td>
<td>127.5</td>
<td>4-Lamp T8HO High-Bay</td>
<td>196.0</td>
<td>$331</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED High-Bay Fixtures, 15,001-20,000 lumens</strong></td>
<td>191.0</td>
<td>6-Lamp T8HO High-Bay</td>
<td>294.0</td>
<td>$482</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED High-Bay Fixtures, &gt; 20,000 lumens</strong></td>
<td>249.7</td>
<td>8-Lamp T8HO High-Bay</td>
<td>392.0</td>
<td>$818</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, &lt;= 2,000 lumens</strong></td>
<td>17.0</td>
<td>25% 73 Watt EISA Inc, 75% 1L T8</td>
<td>42.0</td>
<td>$33</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, 2,001-4,000 lumens</strong></td>
<td>27.8</td>
<td>25% 146 Watt EISA Inc, 75% 2L T8</td>
<td>81.0</td>
<td>$54</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, 4,001-6,000 lumens</strong></td>
<td>51.2</td>
<td>25% 217 Watt EISA Inc, 75% 3L T8</td>
<td>121.0</td>
<td>$125</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, 6,001-8,000 lumens</strong></td>
<td>71.7</td>
<td>25% 292 Watt EISA Inc, 75% 4L T8</td>
<td>159.0</td>
<td>$190</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, 8,001-12,000 lumens</strong></td>
<td>103.5</td>
<td>200W Pulse Start Metal Halide</td>
<td>227.3</td>
<td>$298</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, 12,001-16,000 lumens</strong></td>
<td>143.8</td>
<td>320W Pulse Start Metal Halide</td>
<td>363.6</td>
<td>$450</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><strong>LED Ag Interior Fixtures, 16,001-20,000 lumens</strong></td>
<td>183.3</td>
<td>350W Pulse Start Metal Halide</td>
<td>397.7</td>
<td>$595</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
### LED Category: LED Exterior Fixtures

<table>
<thead>
<tr>
<th>LED Category</th>
<th>EE Measure Description</th>
<th>Watts&lt;sub&gt;EE&lt;/sub&gt;</th>
<th>Baseline Description</th>
<th>Watts&lt;sub&gt;BASE&lt;/sub&gt;</th>
<th>Incremental Cost</th>
<th>Mid Life Savings Adjustment (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LED Ag Interior Fixtures, &gt; 20,000 lumens</td>
<td>305.0</td>
<td>(2) 320W Pulse Start Metal Halide</td>
<td>727.3</td>
<td>$998</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>LED Exterior Fixtures, &lt;= 5,000 lumens</td>
<td>42.6</td>
<td>100W Metal Halide</td>
<td>113.6</td>
<td>$190</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>LED Exterior Fixtures, 5,001-10,000 lumens</td>
<td>68.2</td>
<td>175W Pulse Start Metal Halide</td>
<td>198.9</td>
<td>$287</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>LED Exterior Fixtures, 10,001-15,000 lumens</td>
<td>122.5</td>
<td>250W Pulse Start Metal Halide</td>
<td>284.1</td>
<td>$391</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>LED Exterior Fixtures, &gt; 15,000 lumens</td>
<td>215.0</td>
<td>400W Pulse Start Metal Halide</td>
<td>454.5</td>
<td>$793</td>
<td>N/A</td>
</tr>
</tbody>
</table>

### LED Fixture Component Costs & Lifetime<sup>652</sup>

<table>
<thead>
<tr>
<th>LED Category</th>
<th>EE Measure Description</th>
<th>Lamp Life (hrs)</th>
<th>Total Lamp Replacement Cost</th>
<th>LED Driver Life (hrs)</th>
<th>Total LED Driver Replacement Cost</th>
<th>Lamp Life (hrs)</th>
<th>Total Lamp Replacement Cost</th>
<th>Ballast Life (hrs)</th>
<th>Total Ballast Replacement Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LED Downlight Fixtures</strong></td>
<td>LED Recessed, Surface, Pendant Downlights</td>
<td>50,000</td>
<td>$30.75</td>
<td>70,000</td>
<td>$47.50</td>
<td>2,500</td>
<td>$8.86</td>
<td>40,000</td>
<td>$14.40</td>
</tr>
<tr>
<td><strong>LED Interior Directional</strong></td>
<td>LED Track Lighting</td>
<td>50,000</td>
<td>$39.00</td>
<td>70,000</td>
<td>$47.50</td>
<td>2,500</td>
<td>$12.71</td>
<td>40,000</td>
<td>$11.00</td>
</tr>
<tr>
<td><strong>LED Wall-Wash Fixtures</strong></td>
<td>LED Display Case Light Fixture</td>
<td>50,000</td>
<td>$9.75/ft</td>
<td>70,000</td>
<td>$11.88/ft</td>
<td>2,500</td>
<td>$6.70</td>
<td>40,000</td>
<td>$5.63</td>
</tr>
<tr>
<td><strong>LED Display Case</strong></td>
<td>LED Undercabinet Shelf-Mounted Task Light Fixtures</td>
<td>50,000</td>
<td>$9.75/ft</td>
<td>70,000</td>
<td>$11.88/ft</td>
<td>2,500</td>
<td>$6.70</td>
<td>40,000</td>
<td>$5.63</td>
</tr>
<tr>
<td><strong>LED Display Case</strong></td>
<td>LED Refrigerated Case Light, Horizontal or Vertical</td>
<td>50,000</td>
<td>$8.63/ft</td>
<td>70,000</td>
<td>$9.50/ft</td>
<td>15,000</td>
<td>$1.13</td>
<td>40,000</td>
<td>$8.00</td>
</tr>
<tr>
<td><strong>LED Display Case</strong></td>
<td>LED Freezer Case Light, Horizontal or Vertical</td>
<td>50,000</td>
<td>$7.88/ft</td>
<td>70,000</td>
<td>$7.92/ft</td>
<td>12,000</td>
<td>$0.94</td>
<td>40,000</td>
<td>$6.67</td>
</tr>
<tr>
<td><strong>LED Linear Replacement Lamps</strong></td>
<td>LED 4' Linear Replacement Lamp</td>
<td>50,000</td>
<td>$8.57</td>
<td>70,000</td>
<td>$13.67</td>
<td>24,000</td>
<td>$6.17</td>
<td>40,000</td>
<td>$11.96</td>
</tr>
<tr>
<td><strong>LED Linear Replacement Lamps</strong></td>
<td>LED 2' Linear Replacement Lamp</td>
<td>50,000</td>
<td>$5.76</td>
<td>70,000</td>
<td>$13.67</td>
<td>24,000</td>
<td>$6.17</td>
<td>40,000</td>
<td>$11.96</td>
</tr>
<tr>
<td><strong>LED Troffers</strong></td>
<td>LED 2x2 Recessed Light Fixture, 2000-3500 lumens</td>
<td>50,000</td>
<td>$46.68</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$26.33</td>
<td>40,000</td>
<td>$35.00</td>
</tr>
</tbody>
</table>

<sup>652</sup> Note some measures have blended baselines (T12:T8 80:20). All values are provided to enable calculation of appropriate O&M impacts. Total costs include lamp, labor and disposal cost assumptions where applicable, see "IL LED Lighting Systems TRM Tables" for more information.
<table>
<thead>
<tr>
<th>LED Category</th>
<th>EE Measure Description</th>
<th>Lamp Life (hrs)</th>
<th>Total Lamp Replacement Cost</th>
<th>LED Driver Life (hrs)</th>
<th>Total LED Driver Replacement Cost</th>
<th>Lamp Life (hrs)</th>
<th>Total Lamp Replacement Cost</th>
<th>Ballast Life (hrs)</th>
<th>Total Ballast Replacement Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED 2x2 Recessed Light Fixture, 3501-5000 lumens</td>
<td>50,000</td>
<td>$56.31</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$39.50</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED 2x4 Recessed Light Fixture, 3000-4500 lumens</td>
<td>50,000</td>
<td>$49.58</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$12.33</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED 2x4 Recessed Light Fixture, 4501-6000 lumens</td>
<td>50,000</td>
<td>$57.76</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$18.50</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED 2x4 Recessed Light Fixture, 6001-7500 lumens</td>
<td>50,000</td>
<td>$68.89</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$24.67</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED 1x4 Recessed Light Fixture, 1500-3000 lumens</td>
<td>50,000</td>
<td>$43.43</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$6.17</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED 1x4 Recessed Light Fixture, 3001-4500 lumens</td>
<td>50,000</td>
<td>$52.31</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$12.33</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED 1x4 Recessed Light Fixture, 4501-6000 lumens</td>
<td>50,000</td>
<td>$63.86</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$18.50</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED Surface &amp; Suspended Linear Fixture, &lt;= 3000 lumens</td>
<td>50,000</td>
<td>$45.01</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$6.17</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED Surface &amp; Suspended Linear Fixture, 3001-4500 lumens</td>
<td>50,000</td>
<td>$58.73</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$12.33</td>
<td>40,000</td>
<td>$35.00</td>
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</tr>
<tr>
<td>LED Surface &amp; Suspended Linear Fixture, 4501-6000 lumens</td>
<td>50,000</td>
<td>$73.50</td>
<td>70,000</td>
<td>$40.00</td>
<td>24,000</td>
<td>$18.50</td>
<td>40,000</td>
<td>$35.00</td>
<td></td>
</tr>
<tr>
<td>LED Surface &amp; Suspended Linear Fixture, 6001-7500 lumens</td>
<td>50,000</td>
<td>$88.69</td>
<td>70,000</td>
<td>$40.00</td>
<td>30,000</td>
<td>$26.33</td>
<td>40,000</td>
<td>$60.00</td>
<td></td>
</tr>
<tr>
<td>LED Surface &amp; Suspended Linear Fixture, &gt; 7500 lumens</td>
<td>50,000</td>
<td>$123.91</td>
<td>70,000</td>
<td>$40.00</td>
<td>30,000</td>
<td>$39.50</td>
<td>40,000</td>
<td>$60.00</td>
<td></td>
</tr>
<tr>
<td>LED Low-Bay Fixtures, &lt;= 10,000 lumens</td>
<td>50,000</td>
<td>$90.03</td>
<td>70,000</td>
<td>$62.50</td>
<td>18,000</td>
<td>$64.50</td>
<td>40,000</td>
<td>$92.50</td>
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</tr>
<tr>
<td>LED High-Bay Fixtures, 10,001-15,000 lumens</td>
<td>50,000</td>
<td>$122.59</td>
<td>70,000</td>
<td>$62.50</td>
<td>18,000</td>
<td>$86.00</td>
<td>40,000</td>
<td>$92.50</td>
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</tr>
<tr>
<td>LED Category</td>
<td>EE Measure Description</td>
<td>EE Measure</td>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>----------------------------------------</td>
<td>------------</td>
<td>----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lamp Life (hrs)</td>
<td>Total Lamp Replacement Cost</td>
<td>LED Driver Life (hrs)</td>
<td>Total LED Driver Replacement Cost</td>
<td>Lamp Life (hrs)</td>
<td>Total Lamp Replacement Cost</td>
<td>Ballast Life (hrs)</td>
<td>Total Ballast Replacement Cost</td>
</tr>
<tr>
<td>LED High-Bay Fixtures, 15,001-20,000 lumens</td>
<td>50,000</td>
<td>$157.22</td>
<td>70,000</td>
<td>$62.50</td>
<td>18,000</td>
<td>$129.00</td>
<td>40,000</td>
<td>$117.50</td>
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</tr>
<tr>
<td>LED High-Bay Fixtures, &gt; 20,000 lumens</td>
<td>50,000</td>
<td>$228.52</td>
<td>70,000</td>
<td>$62.50</td>
<td>18,000</td>
<td>$172.00</td>
<td>40,000</td>
<td>$142.50</td>
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</tr>
<tr>
<td>LED Ag Interior Fixtures, &lt;= 2,000 lumens</td>
<td>50,000</td>
<td>$37.00</td>
<td>70,000</td>
<td>$40.00</td>
<td>18,250</td>
<td>$1.23</td>
<td>40,000</td>
<td>$26.25</td>
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</tr>
<tr>
<td>LED Ag Interior Fixtures, 2,001-4,000 lumens</td>
<td>50,000</td>
<td>$44.96</td>
<td>70,000</td>
<td>$40.00</td>
<td>18,250</td>
<td>$1.43</td>
<td>40,000</td>
<td>$26.25</td>
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</tr>
<tr>
<td>LED Ag Interior Fixtures, 4,001-6,000 lumens</td>
<td>50,000</td>
<td>$63.02</td>
<td>70,000</td>
<td>$40.00</td>
<td>18,250</td>
<td>$1.62</td>
<td>40,000</td>
<td>$26.25</td>
<td></td>
</tr>
<tr>
<td>LED Ag Interior Fixtures, 6,001-8,000 lumens</td>
<td>50,000</td>
<td>$79.78</td>
<td>70,000</td>
<td>$40.00</td>
<td>18,250</td>
<td>$1.81</td>
<td>40,000</td>
<td>$26.25</td>
<td></td>
</tr>
<tr>
<td>LED Ag Interior Fixtures, 8,001-12,000 lumens</td>
<td>50,000</td>
<td>$119.91</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$63.00</td>
<td>40,000</td>
<td>$112.50</td>
<td></td>
</tr>
<tr>
<td>LED Ag Interior Fixtures, 12,001-16,000 lumens</td>
<td>50,000</td>
<td>$151.89</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$68.00</td>
<td>40,000</td>
<td>$122.50</td>
<td></td>
</tr>
<tr>
<td>LED Ag Interior Fixtures, 16,001-20,000 lumens</td>
<td>50,000</td>
<td>$184.62</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$73.00</td>
<td>40,000</td>
<td>$132.50</td>
<td></td>
</tr>
<tr>
<td>LED Ag Interior Fixtures, &gt; 20,000 lumens</td>
<td>50,000</td>
<td>$285.75</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$136.00</td>
<td>40,000</td>
<td>$202.50</td>
<td></td>
</tr>
<tr>
<td>LED Exterior Fixtures, &lt;= 5,000 lumens</td>
<td>50,000</td>
<td>$86.92</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$58.00</td>
<td>40,000</td>
<td>$102.50</td>
<td></td>
</tr>
<tr>
<td>LED Exterior Fixtures, 5,001-10,000 lumens</td>
<td>50,000</td>
<td>$111.81</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$63.00</td>
<td>40,000</td>
<td>$112.50</td>
<td></td>
</tr>
<tr>
<td>LED Exterior Fixtures, 10,001-15,000 lumens</td>
<td>50,000</td>
<td>$138.32</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$68.00</td>
<td>40,000</td>
<td>$122.50</td>
<td></td>
</tr>
<tr>
<td>LED Exterior Fixtures, &gt; 15,000 lumens</td>
<td>50,000</td>
<td>$223.67</td>
<td>70,000</td>
<td>$62.50</td>
<td>15,000</td>
<td>$73.00</td>
<td>40,000</td>
<td>$132.50</td>
<td></td>
</tr>
</tbody>
</table>
MEASURE CODE: CI-LTG-LEDB-V06-180101

REVIEW DEADLINE: 1/1/2019
4.5.5 Commercial LED Exit Signs

**Description**

This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a Commercial building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**Definition of Efficient Equipment**

The efficient equipment is assumed to be an exit sign illuminated by LEDs.

**Definition of Baseline Equipment**

The baseline equipment is assumed to be a fluorescent or incandescent model.

**Deemed Lifetime of Efficient Equipment**

The measure life is assumed to be 16 years\(^653\).

**Deemed Measure Cost**

The incremental cost for this measure is assumed to be $30\(^654\).

**Loadshape**

Loadshape C53 - Flat

**Coincidence Factor**

The summer peak coincidence factor for this measure is assumed to be 100\(^655\).

---

### Algorithm

#### Calculation of Savings

**Electric Energy Savings**

\[
\Delta \text{kWh} = \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{HOURS} \times \text{WHF}_e
\]

Where:

<table>
<thead>
<tr>
<th>Baseline Type</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>35W(^656)</td>
</tr>
</tbody>
</table>

---


\(^654\) NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr.

\(^655\) Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.

\(^656\) Based on review of available product.
### Baseline Type and Watts Comparison

<table>
<thead>
<tr>
<th>Baseline Type</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent</td>
<td>11W&lt;sup&gt;657&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unknown (e.g. time of sale)</td>
<td>23W&lt;sup&gt;658&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Watts<sub>EE</sub> = Actual wattage if known, if unknown assume 2W<sup>659</sup>

HOURS = Annual operating hours

= 8766

WHF<sub>e</sub> = Waste heat factor for energy to account for cooling energy savings from efficient lighting

are provided for each building type in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in an office

\[
\Delta kWH = \frac{(35 - 2)}{1000} \times 8766 \times 1.25
\]

= 362 kWh

For example, replacing fluorescent fixture in a hospital

\[
\Delta kWH = \frac{(11 - 2)}{1000} \times 8766 \times 1.35
\]

= 106.5 kWh

### Heating Penalty

If electrically heated building:

\[
\Delta kWH_{\text{heatpenalty}} = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{Hours} \times \text{IFkWh}
\]

Where:

IFkWh = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

For example, replacing incandescent fixture in a heat pump heated office

\[
\Delta kWH_{\text{heatpenalty}} = \frac{(35 - 2)}{1000} \times 8766 \times -0.151
\]

= -43.7 kWh

For example, replacing fluorescent fixture in a heat pump heated hospital

\[
\Delta kWH_{\text{heatpenalty}} = \frac{(11 - 2)}{1000} \times 8766 \times -0.104
\]

= -8.2 kWh

---


<sup>658</sup> ComEd has been using a weighted baseline of 70 percent incandescent and 30 percent compact fluorescent, reflecting program experience and a limited sample of evaluation verification findings that we consider to be reasonable (Navigant, through comment period February 2013)


<sup>660</sup> Negative value because this is an increase in heating consumption due to the efficient lighting.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \left( \frac{WattsBase - WattsEE}{1000} \right) \times WHF_d \times CF \]

Where:

- **WHF_d** = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.
- **CF** = Summer Peak Coincidence Factor for measure = 1.0

<table>
<thead>
<tr>
<th>For example, replacing incandescent fixture in an office</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta kW = (35 - 2)/1000 \times 1.3 \times 1.0 )</td>
</tr>
<tr>
<td>= 0.043 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For example, replacing fluorescent fixture in a hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta kW = (11 - 2)/1000 \times 1.69 \times 1.0 )</td>
</tr>
<tr>
<td>= 0.015 kW</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**

Heating Penalty if natural gas heated building (or if heating fuel is unknown):

\[ \Delta \text{therms} = \left( \frac{(WattsBase - WattsEE)}{1000} \right) \times \text{Hours} \times \text{IFTherms} \]

Where:

- **IFTherms** = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

<table>
<thead>
<tr>
<th>For example, replacing incandescent fixture in an office</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \text{therms} = (35 - 2)/1000 \times 8766 \times -0.016 )</td>
</tr>
<tr>
<td>= -4.63 Therms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>For example, replacing fluorescent fixture in a hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \text{therms} = (11 - 2)/1000 \times 8766 \times -0.011 )</td>
</tr>
<tr>
<td>= - 0.87 Therms</td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

| Baseline Measures | Component | Cost | Life (yrs) |
Baseline Measures

| Lamp       | $7.00\textsuperscript{661} | 1.37 years\textsuperscript{662} |

**Measure Code:** CI-LTG-LEDE-V02-140601

**Review Deadline:** 1/1/2021

\textsuperscript{661} Consistent with assumption for a Standard CFL bulb with an estimated labor cost of $4.50 (assuming $18/hour and a task time of 15 minutes).

\textsuperscript{662} Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.
4.5.6 LED Traffic and Pedestrian Signals

DESCRIPTION
Traffic and pedestrian signals are retrofitted to be illuminated with light emitting diodes (LED) instead of incandescent lamps. Incentive applies for the replacement or retrofit of existing incandescent traffic signals with new LED traffic and pedestrian signal lamps. Each lamp can have no more than a maximum LED module wattage of 25. Incentives are not available for spare lights. Lights must be hardwired and single lamp replacements are not eligible, with the exception of pedestrian hand signals. Eligible lamps must meet the Energy Star Traffic Signal Specification and the Institute for Transportation Engineers specification for traffic signals.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
Refer to the Table titled ‘Traffic Signals Technology Equivalencies’ for efficient technology wattage and savings assumptions.

DEFINITION OF BASELINE EQUIPMENT
Refer to the Table titled ‘Traffic Signals Technology Equivalencies’ for baseline efficiencies and savings assumptions.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The assumed lifetime of an LED traffic signal is 100,000 hours (manufacturer’s estimate), capped at 10 years. The life in years is calculated by dividing 100,000 hrs by the annual operating hours for the particular signal type.

DEEMED MEASURE COST
The actual measure installation cost should be used (including material and labor).

LOADSHAPE
Loadshape C24 - Traffic Signal - Red Balls, always changing or flashing
Loadshape C25 - Traffic Signal - Red Balls, changing day, off night
Loadshape C26 - Traffic Signal - Green Balls, always changing
Loadshape C27 - Traffic Signal - Green Balls, changing day, off night
Loadshape C28 - Traffic Signal - Red Arrows
Loadshape C29 - Traffic Signal - Green Arrows
Loadshape C30 - Traffic Signal - Flashing Yellows
Loadshape C31 - Traffic Signal - “Hand” Don’t Walk Signal
Loadshape C32 - Traffic Signal - “Man” Walk Signal
Loadshape C33 - Traffic Signal - Bi-Modal Walk/Don’t Walk

COINCIDENCE FACTOR
The summer peak coincidence factor (CF) for this measure is dependent on lamp type as below:

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Round, always changing or flashing</td>
<td>0.55</td>
</tr>
</tbody>
</table>

664 Ibid
<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Arrows</td>
<td>0.90</td>
</tr>
<tr>
<td>Green Arrows</td>
<td>0.10</td>
</tr>
<tr>
<td>Yellow Arrows</td>
<td>0.03</td>
</tr>
<tr>
<td>Green Round, always changing or flashing</td>
<td>0.43</td>
</tr>
<tr>
<td>Flashing Yellow</td>
<td>0.50</td>
</tr>
<tr>
<td>Yellow Round, always changing</td>
<td>0.02</td>
</tr>
<tr>
<td>“Hand” Don’t Walk Signal</td>
<td>0.75</td>
</tr>
<tr>
<td>“Man” Walk Signal</td>
<td>0.21</td>
</tr>
</tbody>
</table>

**Algorithm**

**Calculation of Savings**

**Electric Energy Savings**

\[ \Delta \text{kWh} = (W_{\text{base}} - W_{\text{eff}}) \times \text{HOURS} / 1000 \]

Where:

- \( W_{\text{base}} \) = The connected load of the baseline equipment
- \( W_{\text{eff}} \) = The connected load of the efficient equipment
- \( \text{EFLH} \) = Annual operating hours of the lamp
- \( 1000 \) = Conversion factor (W/kW)

**Example**

For example, an 8 inch red, round signal:

\[ \Delta \text{kWh} = ((69 - 7) \times 4818) / 1000 \]

\[ = 299 \text{ kWh} \]

**Summer Coincident Peak Demand Savings**

\[ \Delta \text{kW} = (W_{\text{base}} - W_{\text{eff}}) \times \text{CF} / 1000 \]

Where:

- \( W_{\text{base}} \) = The connected load of the baseline equipment
- \( W_{\text{eff}} \) = The connected load of the efficient equipment
- \( \text{CF} \) = Summer Peak Coincidence Factor for measure
EXAMPLE

For example, an 8 inch red, round signal:

\[
\Delta kW = ((69 - 7) \times 0.55) / 1000
\]
\[
= 0.0341 \text{ kW}
\]

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

REFERENCE TABLES

Traffic Signals Technology Equivalencies

<table>
<thead>
<tr>
<th>Traffic Fixture Type</th>
<th>Fixture Size and Color</th>
<th>Efficient Lamps</th>
<th>Baseline Lamps</th>
<th>HOURS</th>
<th>Efficient Fixture Wattage</th>
<th>Baseline Fixture Wattage</th>
<th>Energy Savings (in kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round Signals</td>
<td>8” Red</td>
<td>LED</td>
<td>Incandescent</td>
<td>4818</td>
<td>7</td>
<td>69</td>
<td>299</td>
</tr>
<tr>
<td>Round Signals</td>
<td>12” Red</td>
<td>LED</td>
<td>Incandescent</td>
<td>4818</td>
<td>6</td>
<td>150</td>
<td>694</td>
</tr>
<tr>
<td>Flashing Signal</td>
<td>8” Red</td>
<td>LED</td>
<td>Incandescent</td>
<td>4380</td>
<td>7</td>
<td>69</td>
<td>272</td>
</tr>
<tr>
<td>Flashing Signal</td>
<td>12” Red</td>
<td>LED</td>
<td>Incandescent</td>
<td>4380</td>
<td>6</td>
<td>150</td>
<td>631</td>
</tr>
<tr>
<td>Flashing Signal</td>
<td>8” Yellow</td>
<td>LED</td>
<td>Incandescent</td>
<td>4380</td>
<td>10</td>
<td>69</td>
<td>258</td>
</tr>
<tr>
<td>Flashing Signal</td>
<td>12” Yellow</td>
<td>LED</td>
<td>Incandescent</td>
<td>4380</td>
<td>13</td>
<td>150</td>
<td>600</td>
</tr>
<tr>
<td>Round Signals</td>
<td>8” Yellow</td>
<td>LED</td>
<td>Incandescent</td>
<td>175</td>
<td>10</td>
<td>69</td>
<td>10</td>
</tr>
<tr>
<td>Round Signals</td>
<td>12” Yellow</td>
<td>LED</td>
<td>Incandescent</td>
<td>175</td>
<td>13</td>
<td>150</td>
<td>24</td>
</tr>
<tr>
<td>Round Signals</td>
<td>8” Green</td>
<td>LED</td>
<td>Incandescent</td>
<td>3767</td>
<td>9</td>
<td>69</td>
<td>266</td>
</tr>
<tr>
<td>Round Signals</td>
<td>12” Green</td>
<td>LED</td>
<td>Incandescent</td>
<td>3767</td>
<td>12</td>
<td>150</td>
<td>520</td>
</tr>
<tr>
<td>Turn Arrows</td>
<td>8” Yellow</td>
<td>LED</td>
<td>Incandescent</td>
<td>701</td>
<td>7</td>
<td>116</td>
<td>76</td>
</tr>
<tr>
<td>Turn Arrows</td>
<td>12” Yellow</td>
<td>LED</td>
<td>Incandescent</td>
<td>701</td>
<td>9</td>
<td>116</td>
<td>75</td>
</tr>
<tr>
<td>Turn Arrows</td>
<td>8” Green</td>
<td>LED</td>
<td>Incandescent</td>
<td>701</td>
<td>7</td>
<td>116</td>
<td>76</td>
</tr>
<tr>
<td>Turn Arrows</td>
<td>12” Green</td>
<td>LED</td>
<td>Incandescent</td>
<td>701</td>
<td>7</td>
<td>116</td>
<td>76</td>
</tr>
<tr>
<td>Pedestrian Sign</td>
<td>12” Hand/Man</td>
<td>LED</td>
<td>Incandescent</td>
<td>8766</td>
<td>8</td>
<td>116</td>
<td>946</td>
</tr>
</tbody>
</table>

Reference specifications for above traffic signal wattages are from the following manufacturers:

1. 8” Incandescent traffic signal bulb: General Electric Traffic Signal Model 17325-69A21/TS
2. 12” Incandescent traffic signal bulb: General Electric Signal Model 35327-150PAR46/TS
4. 8” and 12” LED traffic signals: Leotek Models TSL-ES08 and TSL-ES12
5. 8” LED Yellow Arrow: General Electric Model DR4-YTA2-01A
6. 8” LED Green Arrow: General Electric Model DR4-GCA2-01A
7. 12” LED Yellow Arrow: Dialight Model 431-3334-001X
8. 12” LED Green Arrow: Dialight Model 432-2324-001X
9. LED Hand/Man Pedestrian Sign: Dialight 430-6450-001X

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666 Technical Reference Manual for Ohio, August 6, 2010
MEASURE CODE: CI-LTG-LEDT-V01-120601

REVIEW DEADLINE: 1/1/2019
4.5.7 Lighting Power Density

DESCRIPTION

This measure relates to installation of efficient lighting systems in new construction or substantial renovation of commercial buildings excluding low rise (three stories or less) residential buildings. Substantial renovation is when two or more building systems are renovated, such as shell and heating, heating and lighting, etc. State Energy Code specifies a lighting power density level by building type for both the interior and the exterior. Either the Building Area Method or Space by Space method as defined in IECC 2012 or 2015, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015), can be used for calculating the Interior Lighting Power Density\(^6\). The measure consists of a design that is more efficient (has a lower lighting power density in watts/square foot) than code requires. The IECC applies to both new construction and renovation.

This measure was developed to be applicable to the following program types: NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the lighting system must be more efficient than the baseline Energy Code lighting power density in watts/square foot for either the interior space or exterior space.

DEFINITION OF BASELINE EQUIPMENT

The baseline is assumed to be a lighting power density that meets IECC 2012 or 2015, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

DEEMED CALCULATION FOR THIS MEASURE

Annual kWh Savings

\[
\Delta \text{kWh} = \frac{(\text{WSF}_{\text{base}} - \text{WSF}_{\text{effic}})}{1000} \times \text{SF} \times \text{Hours} \times \text{WHF}_e
\]

Summer Coincident Peak kW Savings

\[
\Delta \text{kW} = \frac{(\text{WSF}_{\text{base}} - \text{WSF}_{\text{effic}})}{1000} \times \text{SF} \times \text{CF} \times \text{WHF}_d
\]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 15 years\(^7\).

DEEMED MEASURE COST

The actual incremental cost over a baseline system will be collected from the customer if possible or developed on a fixture by fixture basis.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting

---

\(^6\) Refer to the referenced code documents for specifics on calculating lighting power density using either the whole building method (IECC) or the Space by Space method (ASHRAE 90.1).

Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the building type.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ENERGY SAVINGS**

\[ \Delta kWh = \frac{(WSF_{\text{base}}-WSF_{\text{effic}})}{1000} \times SF \times \text{Hours} \times WHF_e \]

Where:

- \( WSF_{\text{base}} \) = Baseline lighting watts per square foot or linear foot as determined by building or space type. Whole building analysis values are presented in the Reference Tables below.\(^{669}\)
- \( WSF_{\text{effic}} \) = The actual installed lighting watts per square foot or linear foot.
- \( SF \) = Provided by customer based on square footage of the building area applicable to the lighting design for new building.
- \( \text{Hours} \) = Annual site-specific hours of operation of the lighting equipment collected from the customer. If not available, use building area type as provided in the Reference Table in Section 4.5, Fixture annual operating hours.
- \( WHF_e \) = Waste Heat Factor for Energy to account for cooling savings from efficient lighting is as provided in the Reference Table in Section 4.5 by building type. If building is not cooled \( WHF_e \) is 1.

**HEATING PENALTY**

If electrically heated building:

\[ \Delta kWh_{\text{heatpenalty}} = \frac{(WSF_{\text{base}}-WSF_{\text{effic}})}{1000} \times SF \times \text{Hours} \times -IFkWh \]

Where:

- \( IFkWh \) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected.

\(^{669}\)See IECC 2012 and 2015 - Reference Code documentation for additional information.

\(^{670}\)Negative value because this is an increase in heating consumption due to the efficient lighting.
by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \frac{(WSF_{\text{base}} - WSF_{\text{effic}})}{1000 \times SF} \times CF \times WHF_d \]

Where:

- \( WHF_d \) = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings as is provided in the Reference Table in Section 4.5 by building type. If building is not cooled \( WHF_d \) is 1.
- \( CF \) = Summer Peak Coincidence Factor for measure as is provided in the Reference Table in Section 4.5 by building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

**NATURAL GAS ENERGY SAVINGS**

\[ \Delta \text{Therms} = \frac{(WSF_{\text{base}} - WSF_{\text{effic}})}{1000 \times SF} \times \text{Hours} \times -\text{IFTherms} \]

Where:

- \( \text{IFTherms} \) = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is provided in the Reference Table in Section 4.5 by building type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Lighting Power Density Values from IECC 2012 and 2015 for Interior Commercial New Construction and Substantial Renovation Building Area Method:

<table>
<thead>
<tr>
<th>Building Area Type</th>
<th>IECC 2012 Lighting Power Density (w/ft²)</th>
<th>IECC 2015 Lighting Power Density (w/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automotive Facility</td>
<td>0.9</td>
<td>0.80</td>
</tr>
<tr>
<td>Convention Center</td>
<td>1.2</td>
<td>1.01</td>
</tr>
<tr>
<td>Court House</td>
<td>1.2</td>
<td>1.01</td>
</tr>
<tr>
<td>Dining: Bar Lounge/Leisure</td>
<td>1.3</td>
<td>1.01</td>
</tr>
<tr>
<td>Dining: Cafeteria/Fast Food</td>
<td>1.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Dining: Family</td>
<td>1.6</td>
<td>0.95</td>
</tr>
<tr>
<td>Dormitory</td>
<td>1.0</td>
<td>0.57</td>
</tr>
<tr>
<td>Exercise Center</td>
<td>1.0</td>
<td>0.84</td>
</tr>
<tr>
<td>Fire station</td>
<td>0.8</td>
<td>0.67</td>
</tr>
<tr>
<td>Gymnasium</td>
<td>1.1</td>
<td>0.94</td>
</tr>
</tbody>
</table>

\(^{671}\) In cases where both a general building area type and a more specific building area type are listed, the more specific building area type shall apply.
<table>
<thead>
<tr>
<th>Building Area Type</th>
<th>IECC 2012 Lighting Power Density (w/ft²)</th>
<th>IECC 2015 Lighting Power Density (w/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare – clinic</td>
<td>1.0</td>
<td>0.90</td>
</tr>
<tr>
<td>Hospital</td>
<td>1.2</td>
<td>1.05</td>
</tr>
<tr>
<td>Hotel</td>
<td>1.0</td>
<td>0.87</td>
</tr>
<tr>
<td>Library</td>
<td>1.3</td>
<td>1.19</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>1.3</td>
<td>1.17</td>
</tr>
<tr>
<td>Motel</td>
<td>1.0</td>
<td>0.87</td>
</tr>
<tr>
<td>Motion Picture Theater</td>
<td>1.2</td>
<td>0.76</td>
</tr>
<tr>
<td>Multifamily</td>
<td>0.7</td>
<td>0.51</td>
</tr>
<tr>
<td>Museum</td>
<td>1.1</td>
<td>1.02</td>
</tr>
<tr>
<td>Office</td>
<td>0.9</td>
<td>0.82</td>
</tr>
<tr>
<td>Parking Garage</td>
<td>0.3</td>
<td>0.21</td>
</tr>
<tr>
<td>Penitentiary</td>
<td>1.0</td>
<td>0.81</td>
</tr>
<tr>
<td>Performing Arts Theater</td>
<td>1.6</td>
<td>1.39</td>
</tr>
<tr>
<td>Police Station</td>
<td>1.0</td>
<td>0.87</td>
</tr>
<tr>
<td>Post Office</td>
<td>1.1</td>
<td>0.87</td>
</tr>
<tr>
<td>Religious Building</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Retail 672</td>
<td>1.4</td>
<td>1.26</td>
</tr>
<tr>
<td>School/University</td>
<td>1.2</td>
<td>0.87</td>
</tr>
<tr>
<td>Sports Arena</td>
<td>1.1</td>
<td>0.91</td>
</tr>
<tr>
<td>Town Hall</td>
<td>1.1</td>
<td>0.89</td>
</tr>
<tr>
<td>Transportation</td>
<td>1.0</td>
<td>0.70</td>
</tr>
<tr>
<td>Warehouse</td>
<td>0.6</td>
<td>0.66</td>
</tr>
<tr>
<td>Workshop</td>
<td>1.4</td>
<td>1.19</td>
</tr>
</tbody>
</table>

671 Where lighting equipment is specified to be installed to highlight specific merchandise in addition to lighting equipment specified for general lighting and is switched or dimmed on circuits different from the circuits for general lighting, the small of the actual wattage of the lighting equipment installed specifically for merchandise, or additional lighting power as determined below shall be added to the interior lighting power determined in accordance with this line item.
## Lighting Power Density Values from IECC 2012 for Interior Commercial New Construction and Substantial Renovation

**Space by Space Method:**

<table>
<thead>
<tr>
<th>Common Space-by-Space Types</th>
<th>LPD (w/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrium – First 40 feet in height</td>
<td>0.03 per ft.²</td>
</tr>
<tr>
<td>Atrium – Above 40 feet in height</td>
<td>0.02 per ft.²</td>
</tr>
<tr>
<td>Audience/seating area – permanent</td>
<td>1.30</td>
</tr>
<tr>
<td>Auditorium</td>
<td>0.9</td>
</tr>
<tr>
<td>Conference/meeting/multipurpose</td>
<td>1.2</td>
</tr>
<tr>
<td>Corridor/transition</td>
<td>0.7</td>
</tr>
<tr>
<td>Dining area</td>
<td>1.40</td>
</tr>
<tr>
<td>Bar/lounge/leisure dining</td>
<td>1.1</td>
</tr>
<tr>
<td>Family dining area</td>
<td>1.40</td>
</tr>
<tr>
<td>Dressing/fitting room performing arts theater</td>
<td>1.1</td>
</tr>
<tr>
<td>Electrical/mechanical</td>
<td>1.10</td>
</tr>
<tr>
<td>Food preparation</td>
<td>1.20</td>
</tr>
<tr>
<td>Laboratory for classrooms</td>
<td>1.3</td>
</tr>
<tr>
<td>Laboratory for medical/industrial/research</td>
<td>1.8</td>
</tr>
<tr>
<td>Lobby</td>
<td>1.10</td>
</tr>
<tr>
<td>Lobby for performing arts theater</td>
<td>3.3</td>
</tr>
<tr>
<td>Lobby for motion picture theater</td>
<td>1.0</td>
</tr>
<tr>
<td>Locker room</td>
<td>0.80</td>
</tr>
<tr>
<td>Lounge recreation</td>
<td>0.8</td>
</tr>
<tr>
<td>Office – enclosed</td>
<td>1.1</td>
</tr>
<tr>
<td>Office – open plan</td>
<td>1.0</td>
</tr>
<tr>
<td>Restroom</td>
<td>1.0</td>
</tr>
<tr>
<td>Sales area</td>
<td>1.6²</td>
</tr>
<tr>
<td>Stairway</td>
<td>0.70</td>
</tr>
<tr>
<td>Storage</td>
<td>0.8</td>
</tr>
<tr>
<td>Workshop</td>
<td>1.50</td>
</tr>
<tr>
<td>Courthouse/police station/penitentiary</td>
<td>1.90</td>
</tr>
<tr>
<td>Courtroom</td>
<td>1.1</td>
</tr>
<tr>
<td>Confinement cells</td>
<td>1.30</td>
</tr>
<tr>
<td>Judge chambers</td>
<td>0.5</td>
</tr>
<tr>
<td>Pentenitary audience seating</td>
<td>1.3</td>
</tr>
<tr>
<td>Pentenitary classroom</td>
<td>1.1</td>
</tr>
<tr>
<td>BUILDING SPECIFIC SPACE-BY-SPACE TYPES</td>
<td></td>
</tr>
<tr>
<td>Automotive – service/repair</td>
<td>0.70</td>
</tr>
<tr>
<td>Bank/Office – banking activity area</td>
<td>1.5</td>
</tr>
<tr>
<td>Dormitory living quarters</td>
<td>1.10</td>
</tr>
<tr>
<td>Gymnasium/fitness center</td>
<td>0.9</td>
</tr>
<tr>
<td>Fitness area</td>
<td>0.40</td>
</tr>
<tr>
<td>Gymnasium audience/seating</td>
<td>1.40</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>BUILDING SPECIFIC SPACE-BY-SPACE TYPES</th>
<th>LPD (w/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sports arena</td>
<td></td>
</tr>
<tr>
<td>Audience seating</td>
<td>0.4</td>
</tr>
<tr>
<td>Court sports area – Class 4</td>
<td>0.7</td>
</tr>
<tr>
<td>Court sports area – Class 3</td>
<td>1.2</td>
</tr>
<tr>
<td>Court sports area – Class 2</td>
<td>1.9</td>
</tr>
<tr>
<td>Court sports area – Class 1</td>
<td>3.0</td>
</tr>
<tr>
<td>Ring sports area</td>
<td>2.7</td>
</tr>
<tr>
<td>Transportation</td>
<td></td>
</tr>
<tr>
<td>Airline/train/bus baggage area</td>
<td>1.00</td>
</tr>
<tr>
<td>Airport concourse</td>
<td>0.60</td>
</tr>
<tr>
<td>Terminal – ticket counter</td>
<td>1.30</td>
</tr>
<tr>
<td>Warehouse</td>
<td></td>
</tr>
<tr>
<td>Fire material storage</td>
<td>1.40</td>
</tr>
<tr>
<td>Medium/bulky material</td>
<td>0.60</td>
</tr>
</tbody>
</table>
Lighting Power Density Values from IECC 2015 for Interior Commercial New Construction and Substantial Renovation
Space by Space Method:

<table>
<thead>
<tr>
<th>COMMON SPACE TYPES*</th>
<th>LPD (watts/sq.ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Amnun</strong></td>
<td></td>
</tr>
<tr>
<td>Less than 40 feet in height</td>
<td>0.03 per foot in total height</td>
</tr>
<tr>
<td>Greater than 40 feet in height</td>
<td>0.40 + 0.02 per foot in total height</td>
</tr>
<tr>
<td><strong>Audience seating area</strong></td>
<td></td>
</tr>
<tr>
<td>In an auditorium</td>
<td>0.63</td>
</tr>
<tr>
<td>In a convention center</td>
<td>0.82</td>
</tr>
<tr>
<td>In a gymnasium</td>
<td>0.65</td>
</tr>
<tr>
<td>In a motion picture theater</td>
<td>1.14</td>
</tr>
<tr>
<td>In a penitentiary</td>
<td>0.28</td>
</tr>
<tr>
<td>In a performing arts theater</td>
<td>2.43</td>
</tr>
<tr>
<td>In a religious building</td>
<td>1.53</td>
</tr>
<tr>
<td>In a sports arena</td>
<td>0.43</td>
</tr>
<tr>
<td>Otherwise</td>
<td>0.43</td>
</tr>
<tr>
<td><strong>Banking activity area</strong></td>
<td>1.01</td>
</tr>
<tr>
<td><strong>Breakroom (See Lounge/Breakroom)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Classroom/lecture hall/training room</strong></td>
<td></td>
</tr>
<tr>
<td>In a penitentiary</td>
<td>1.34</td>
</tr>
<tr>
<td>Otherwise</td>
<td>1.24</td>
</tr>
<tr>
<td>Conference/meeting/multipurpose room</td>
<td>1.23</td>
</tr>
<tr>
<td><strong>Copy/print room</strong></td>
<td>0.72</td>
</tr>
<tr>
<td><strong>Corridor</strong></td>
<td></td>
</tr>
<tr>
<td>In a facility for the visually impaired (and not used primarily by the staff)</td>
<td>0.92</td>
</tr>
<tr>
<td>In a hospital</td>
<td>0.79</td>
</tr>
<tr>
<td>In a manufacturing facility</td>
<td>0.41</td>
</tr>
<tr>
<td>Otherwise</td>
<td>0.66</td>
</tr>
<tr>
<td><strong>Courtroom</strong></td>
<td>1.72</td>
</tr>
<tr>
<td><strong>Computer room</strong></td>
<td>1.71</td>
</tr>
<tr>
<td><strong>Dining area</strong></td>
<td></td>
</tr>
<tr>
<td>In a penitentiary</td>
<td>0.96</td>
</tr>
<tr>
<td>In a facility for the visually impaired (and not used primarily by the staff)</td>
<td>1.9</td>
</tr>
<tr>
<td>In bar/lounge or leisure dining</td>
<td>1.07</td>
</tr>
<tr>
<td>In cafeteria or fast food dining</td>
<td>0.65</td>
</tr>
<tr>
<td>In family dining</td>
<td>0.89</td>
</tr>
<tr>
<td>Otherwise</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>Electrical/mechanical room</strong></td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Emergency vehicle garage</strong></td>
<td>0.56</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Building Type</th>
<th>Specific Space Types</th>
<th>LPO (watts/sq.ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthcare Facility</td>
<td>In an exam/treatment room</td>
<td>1.66</td>
</tr>
<tr>
<td></td>
<td>In an imaging room</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>In a medical supply room</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>In a nursery</td>
<td>0.88</td>
</tr>
<tr>
<td></td>
<td>In a nurse's station</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>In an operating room</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>In a patient room</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>In a physical therapy room</td>
<td>0.91</td>
</tr>
<tr>
<td></td>
<td>In a recovery room</td>
<td>1.15</td>
</tr>
<tr>
<td>Library</td>
<td>In a reading area</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td>In the stacks</td>
<td>1.71</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>In a detailed manufacturing area</td>
<td>1.29</td>
</tr>
<tr>
<td></td>
<td>In an equipment room</td>
<td>0.74</td>
</tr>
<tr>
<td></td>
<td>In an extra high bay area (greater than 50’ floor-to-ceiling height)</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>In a high bay area (25-50’ floor-to-ceiling height)</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>In a low bay area (less than 25’ floor-to-ceiling height)</td>
<td>1.19</td>
</tr>
<tr>
<td>Museum</td>
<td>In a general exhibition area</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>In a restoration room</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>Performing arts theater—dressing room</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Post Office—Sorting Area</td>
<td>0.94</td>
</tr>
<tr>
<td>Religious Buildings</td>
<td>In a fellowship hall</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>In a worship/pulpit/choir area</td>
<td>1.53</td>
</tr>
<tr>
<td>Retail Facilities</td>
<td>In a dressing/fitting room</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>In a mall concourse</td>
<td>1.1</td>
</tr>
<tr>
<td>Sports Arena—Playing Area</td>
<td>For a Class I facility</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>For a Class II facility</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>For a Class III facility</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>For a Class IV facility</td>
<td>1.2</td>
</tr>
<tr>
<td>Transportation Facility</td>
<td>In a baggage/carousel area</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>In an airport concourse</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>At a terminal ticket counter</td>
<td>0.8</td>
</tr>
<tr>
<td>Warehouse—Storage Area</td>
<td>For medium to bulky, palletized items</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>For smaller, hand-carried items</td>
<td>0.95</td>
</tr>
</tbody>
</table>

a. In cases where both a common space type and a building area specific space type are listed, the building area specific space type shall apply.
b. A “Facility for the Visually Impaired” is a facility that is licensed or will be licensed by local or state authorities for senior long-term care, adult daycares, senior support or people with special visual needs.
The exterior lighting design will be based on the building location and the applicable “Lighting Zone” as defined in IECC 2015 Table C405.5.2(1) which follows. This table is identical to IECC 2012 Table C405.62(1).

### TABLE C405.5.2(1)
**EXTERIOR LIGHTING ZONES**

<table>
<thead>
<tr>
<th>LIGHTING ZONE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Developed areas of national parks, state parks, forest land, and rural areas</td>
</tr>
<tr>
<td>2</td>
<td>Areas predominantly consisting of residential zoning, neighborhood business districts, light industrial with limited nighttime use and residential mixed-use areas</td>
</tr>
<tr>
<td>3</td>
<td>All other areas not classified as lighting zone 1, 2 or 4</td>
</tr>
<tr>
<td>4</td>
<td>High-activity commercial districts in major metropolitan areas as designated by the local land use planning authority</td>
</tr>
</tbody>
</table>
The lighting power density savings will be based on reductions below the allowable design levels as specified in IECC 2012 Table C405.6.2(2) or IECC 2015 Table C405.5.2(2).

### Allowable Design Levels from IECC 2012

<table>
<thead>
<tr>
<th>Base Site Allowance (Based on the allowable design levels as specified in IECC 2012 Table C405.6.2(2) or IECC 2015 Table C405.5.2(2).)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 1</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>500 W</td>
</tr>
</tbody>
</table>

**Uncovered Parking Areas**

<table>
<thead>
<tr>
<th>Parking areas and drives</th>
<th>0.04 W/ft²</th>
<th>0.06 W/ft²</th>
<th>0.10 W/ft²</th>
<th>0.13 W/ft²</th>
</tr>
</thead>
</table>

**Building Grounds**

<table>
<thead>
<tr>
<th>Walkways less than 10 feet wide or greater, plaza areas special feature areas</th>
<th>0.14 W/ft²</th>
<th>0.14 W/ft²</th>
<th>0.16 W/ft²</th>
<th>0.2 W/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairways</td>
<td>0.75 W/ft²</td>
<td>1.0 W/ft²</td>
<td>1.0 W/ft²</td>
<td>1.0 W/ft²</td>
</tr>
<tr>
<td>Pedestrian tunnels</td>
<td>0.15 W/ft²</td>
<td>0.15 W/ft²</td>
<td>0.2 W/ft²</td>
<td>0.3 W/ft²</td>
</tr>
</tbody>
</table>

**Building Entrances and Exits**

<table>
<thead>
<tr>
<th>Main entries, 20 W/linear foot of door width</th>
<th>20 W/linear foot of door width</th>
<th>30 W/linear foot of door width</th>
<th>30 W/linear foot of door width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other doors, 20 W/linear foot of door width</td>
<td>20 W/linear foot of door width</td>
<td>20 W/linear foot of door width</td>
<td>20 W/linear foot of door width</td>
</tr>
<tr>
<td>Entry canopies</td>
<td>0.25 W/ft²</td>
<td>0.25 W/ft²</td>
<td>0.4 W/ft²</td>
</tr>
</tbody>
</table>

**Sales Canopies**

<table>
<thead>
<tr>
<th>Free-standing and attached</th>
<th>0.6 W/ft²</th>
<th>0.6 W/ft²</th>
<th>0.8 W/ft²</th>
<th>1.0 W/ft²</th>
</tr>
</thead>
</table>

**Outdoor Sales**

<table>
<thead>
<tr>
<th>Open areas (including vehicle sales loss)</th>
<th>0.25 W/ft²</th>
<th>0.25 W/ft²</th>
<th>0.5 W/ft²</th>
<th>0.7 W/ft²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street frontage for vehicle sales lots in addition to &quot;open area&quot; allowance</td>
<td>No allowance</td>
<td>10 W/linear foot</td>
<td>10 W/linear foot</td>
<td>30 W/linear foot</td>
</tr>
</tbody>
</table>

**Nontradable Surfaces**

<table>
<thead>
<tr>
<th>Building facades</th>
<th>No allowance</th>
<th>0.1 W/ft² for each illuminated wall or surface</th>
<th>0.15 W/ft² for each illuminated wall or surface</th>
<th>0.2 W/ft² for each illuminated wall or surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated teller machines and night depositories, 270 W per location plus 90 W per additional ATM per location</td>
<td>270 W per location plus 90 W per additional ATM per location</td>
<td>270 W per location plus 90 W per additional ATM per location</td>
<td>270 W per location plus 90 W per additional ATM per location</td>
<td>270 W per location plus 90 W per additional ATM per location</td>
</tr>
<tr>
<td>Entrance ways and gatehouse inspection stations at guarded facilities, 0.75 W/ft² of covered and uncovered area</td>
<td>0.75 W/ft² of covered and uncovered area</td>
<td>0.75 W/ft² of covered and uncovered area</td>
<td>0.75 W/ft² of covered and uncovered area</td>
<td>0.75 W/ft² of covered and uncovered area</td>
</tr>
<tr>
<td>Loading areas for law enforcement, fire, ambulance and other emergency service vehicles, 0.5 W/ft² of covered and uncovered area</td>
<td>0.5 W/ft² of covered and uncovered area</td>
<td>0.5 W/ft² of covered and uncovered area</td>
<td>0.5 W/ft² of covered and uncovered area</td>
<td>0.5 W/ft² of covered and uncovered area</td>
</tr>
<tr>
<td>Drive-up windows/doors, 400 W per drive-through</td>
<td>400 W per drive-through</td>
<td>400 W per drive-through</td>
<td>400 W per drive-through</td>
<td>400 W per drive-through</td>
</tr>
<tr>
<td>Parking near 24-hour retail entrances, 800 W per main entry</td>
<td>800 W per main entry</td>
<td>800 W per main entry</td>
<td>800 W per main entry</td>
<td>800 W per main entry</td>
</tr>
</tbody>
</table>

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m².
### Allowable Design Levels from IECC 2015

<table>
<thead>
<tr>
<th>TABLE C405.5.2(2)</th>
<th>INDIVIDUAL LIGHTING POWER ALLOWANCES FOR BUILDING EXTERIORS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIGHTING ZONES</strong></td>
<td></td>
</tr>
<tr>
<td>Zone 1</td>
<td>Zone 2</td>
</tr>
<tr>
<td>Base Site Allowance (Base allowance in usable im tradable or nontradable surfaces)</td>
<td>500 W</td>
</tr>
<tr>
<td>Uncovered Parking Areas</td>
<td>0.04 W/ft²</td>
</tr>
<tr>
<td>Building Grounds</td>
<td>0.7 W/linear foot</td>
</tr>
<tr>
<td>Walkways less than 10 feet wide</td>
<td>0.14 W/ft²</td>
</tr>
<tr>
<td>Walkways 10 feet wide or greater, plaza areas special feature areas</td>
<td>0.75 W/ft²</td>
</tr>
<tr>
<td>Starways</td>
<td>0.15 W/ft²</td>
</tr>
<tr>
<td>Pedestrian tunnels</td>
<td>0.25 W/ft²</td>
</tr>
<tr>
<td><strong>Building Entrances and Exit</strong></td>
<td>20 W/linear foot of door width</td>
</tr>
<tr>
<td>Main entries</td>
<td>0.25 W/ft²</td>
</tr>
<tr>
<td>Other doors</td>
<td>0.25 W/ft²</td>
</tr>
<tr>
<td>Entry canopies</td>
<td>0.25 W/ft²</td>
</tr>
<tr>
<td>Sales Canopies</td>
<td>0.6 W/ft²</td>
</tr>
<tr>
<td>Outdoor Sales</td>
<td>0.25 W/ft²</td>
</tr>
<tr>
<td>Nontradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific location and cannot be used between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the &quot;Uncovered Surfaces&quot; section of this table.)</td>
<td></td>
</tr>
<tr>
<td>Building facades</td>
<td>No allowance</td>
</tr>
<tr>
<td>Automated teller machines (ATM) and night depositories</td>
<td>0.70 W per location plus 90 W per additional ATM per location</td>
</tr>
<tr>
<td>Entrances and gatehouse inspection stations at guarded facilities</td>
<td>0.75 W/ft² of covered and uncovered area</td>
</tr>
<tr>
<td>Loading areas for law enforcement, fire, ambulance and other emergency service vehicles</td>
<td>0.5 W/ft² of covered and uncovered area</td>
</tr>
<tr>
<td>Drive-up windows/doors</td>
<td>400 W per drive-through</td>
</tr>
<tr>
<td>Parking near 24-hour retail entrances</td>
<td>800 W per main entry</td>
</tr>
</tbody>
</table>

For SI: 1 foot = 304.8 mm, 1 watt per square foot = W/0.0929 m², W = watts.

**MEASURE CODE:** CI-LTG-LPDE-V03-160601

**REVIEW DEADLINE:** 1/1/2020
4.5.8 Miscellaneous Commercial/Industrial Lighting

DESCRIPTION

This measure is designed to calculate savings from energy efficient lighting upgrades that are not captured in other measures within the TRM. If a lighting project fits the measure description in sections 4.5.1-4.5.4, then those criteria, definitions, and calculations should be used.

Unlike other lighting measures this one applies only to RF applications (because there is no defined baseline for TOS or NC applications).

DEFINITION OF EFFICIENT EQUIPMENT

A lighting fixture that replaces an existing fixture to provide the same or greater lumen output at a lower kW consumption.

DEFINITION OF BASELINE EQUIPMENT

The definition of baseline equipment is the existing lighting fixture.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The deemed lifetime of the efficient equipment fixture, regardless of program type is 15 years673.

DEEMED MEASURE COST

The actual cost of the efficient light fixture should be used.

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

---

673 15 years from GDS Measure Life Report, June 2007
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh = \left( \frac{(Watts_{\text{base}} - Watts_{\text{EE}})}{1000} \right) \times \text{Hours} \times WHF_e \times \text{ISR} \]

Where:

- **Watts\text{base}** = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and ballast factor (if applicable) and number of fixtures.
  - = Actual
- **Watts\text{EE}** = New Input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor (if applicable) (if applicable) and number of fixtures.
  - = Actual
- **Hours** = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours, by building type. If hours or building type are unknown, use the Miscellaneous value.
- **WHF\text{e}** = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.
- **ISR** = In Service Rate or the percentage of units rebated that get installed.
  - = 100%\textsuperscript{674} if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

<table>
<thead>
<tr>
<th>Weigted Average 1\textsuperscript{st} year In Service Rate (ISR)</th>
<th>2\textsuperscript{nd} year Installations</th>
<th>3\textsuperscript{rd} year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>75.5%\textsuperscript{675}</td>
<td>12.1%</td>
<td>10.3%</td>
<td>98.0%\textsuperscript{676}</td>
</tr>
</tbody>
</table>

HEATING PENALTY

If electrically heated building:

\[ \Delta kWh_{\text{heatpenalty}} = \left( \frac{(Watts_{\text{base}} - Watts_{\text{EE}})}{1000} \right) \times \text{ISR} \times \text{Hours} \times -IFkWh \]

Where:

\textsuperscript{674}Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an “In-Service Rate” when commercial customers complete an application form.

\textsuperscript{675} 1\textsuperscript{st} year in service rate is based upon review of PY4-5 evaluations from ComEd’s commercial lighting program (BILD) (see ‘IL Commercial Lighting ISR.xls’ for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

\textsuperscript{676} The 98% Lifetime ISR assumption is based upon review of two evaluations:

‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2\textsuperscript{nd} and 3\textsuperscript{rd} year installations should be counted as part of those future program year savings.

\textsuperscript{677}Negative value because this is an increase in heating consumption due to the efficient lighting.
IFkWh = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

DEFERRED INSTALLS

As presented above, if a sign off form is not completed the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.

Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

SUMMER COINCIDENT DEMAND SAVINGS

\[ \Delta kW = \left( \frac{\text{Watts}_{\text{base}} - \text{Watts}_{\text{EE}}}{1000} \right) \times \text{WHF}_d \times \text{CF} \times \text{ISR} \]

Where:

\[ \text{WHF}_d \]

= Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

\[ \text{CF} \]

= Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

Other factors as defined above

NATURAL GAS ENERGY SAVINGS

\[ \Delta \text{Therms}^{678} = \left( \frac{\text{Watts}_{\text{base}} - \text{Watts}_{\text{EE}}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{IFT}\text{erms} \]

Where:

\[ \text{IFT}\text{erms} \]

= Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is selected from the Reference Table in Section 6.5 for each building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

If there are differences between the maintenance of the efficient and baseline lighting system then they should be evaluated on a project-by-project basis.

\[^{678}\text{Negative value because this is an increase in heating consumption due to the efficient lighting.}\]
MEASURE CODE: CI-LTG-MSCI-V02-140601

REVIEW DEADLINE: 1/1/2021
4.5.9 Multi-Level Lighting Switch

DESCRIPTION
This measure relates to the installation of multi-level lighting switches on an existing lighting system.
This measure can only relate to the adding of a new control in an existing building, since multi-level switching is required in the Commercial new construction building energy code (IECC 2012/2015).
This measure was developed to be applicable to the following program types: RF.
If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, the efficient system is assumed to be a lighting system controlled by multi-level lighting controls.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is assumed to be an uncontrolled lighting system where all lights in a given area are on the same circuit or all circuits come on at the same time.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life for all lighting controls is assumed to be 8 years\(^7\).

DEEMED MEASURE COST
When available, the actual cost of the measure shall be used. When not available, the incremental capital cost for this measure is assumed to be $274\(^8\).

LOADSHAPE
Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indus. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indus. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indus. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indus. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

\(^7\) Consistent with Occupancy Sensor control measure.
COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh = KW_{Controlled} \times \text{Hours} \times \text{ESF} \times WHF_e \]

Where:

- \( KW_{Controlled} \) = Total lighting load connected to the control in kilowatts.
- \( \text{Hours} \) = Actual total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown building type, use the Miscellaneous value.
- \( \text{ESF} \) = Energy Savings factor (represents the percentage reduction to the KWcontrolled due to the use of multi-level switching).
- \( \text{WHF}_e \) = Energy Savings factor (represents the percentage reduction to the KWcontrolled due to the use of multi-level switching).

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Energy Savings Factor (ESF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Office</td>
<td>21.6%</td>
</tr>
<tr>
<td>Open Office</td>
<td>16.0%</td>
</tr>
<tr>
<td>Retail</td>
<td>14.8%</td>
</tr>
<tr>
<td>Classrooms</td>
<td>8.3%</td>
</tr>
<tr>
<td>Unknown, average</td>
<td>15%</td>
</tr>
</tbody>
</table>

WHF\(_e\) = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is uncooled, the value is 1.0.

HEATING PENALTY

If electrically heated building:

\[ \Delta kWh_{heatpenalty} = KW_{Controlled} \times \text{Hours} \times \text{ESF} \times \text{IFkWh} \]

Where:

- \( \text{IFkWh} \) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected.

\(^{681}\) Based on results from “Lighting Controls Effectiveness Assessment: Final Report on Bi-Level Lighting Study” published by the California Public Utilities Commission (CPUC), prepared by ADM Associates.

\(^{682}\) Negative value because this is an increase in heating consumption due to the efficient lighting.
by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = kW_{controlled} \times ESF \times WHF_d \times CF \]

Where:

- **WHF_d** = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is un-cooled WHF_d is 1.

- **CF** = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value of 0.66683.

**NATURAL GAS ENERGY SAVINGS**

\[ \Delta \text{therms} = kW_{controlled} \times \text{Hours} \times ESF \times IF\text{Therms} \]

Where:

- **IFTherms** = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by building type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-LTG-MLLC-V03-160601**

**REVIEW DEADLINE: 1/1/2021**

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683 By applying the ESF and the same coincidence factor for general lighting savings we are in essence assuming that the savings from multi-level switching are as likely during peak periods as any other time. In the absence of better information this seems like a reasonable assumption and if anything may be on the conservative side since you might expect the peak periods to be generally sunnier and therefore more likely to have lower light levels. It is also consistent with the control type reducing the wattage lighting load, the same as the general lighting measures.
4.5.10 Occupancy Sensor Lighting Controls

DESCRIPTION

This measure relates to the installation of new occupancy sensors on a new or existing lighting system. Lighting control types covered by this measure include wall, ceiling or fixture mounted occupancy sensors. Passive infrared, ultrasonic detectors and fixture-mounted sensors or sensors with a combination thereof are eligible. Lighting controls required by state energy codes are not eligible. This must be a new installation and may not replace an existing lighting occupancy sensor control.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the existing system is assumed to be manually controlled or an uncontrolled lighting system which is being controlled by one of the lighting controls systems listed above. This measure is intended for controlling interior lighting only.

A subset of occupancy sensors are those that are programmed as “vacancy” sensors. To qualify as a vacancy sensor, the control must be configured such that manual input is required to turn on the controlled lighting and the control automatically turns the lighting off. Additional savings are achieved compared to standard occupancy sensors because lighting does not automatically turn on and occupants may decide to not turn it on. Note that vacancy sensors are not a viable option for many applications where standard occupancy sensors should be used instead.

DEFINITION OF BASELINE EQUIPMENT

The baseline is assumed to be a lighting system uncontrolled by occupancy.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life for all lighting controls is assumed to be 8 years\(^\text{684}\).

DEEMED MEASURE COST

When available, the actual cost of the measure shall be used. When not available, the following default values are provided:

<table>
<thead>
<tr>
<th>Lighting control type</th>
<th>Cost(^\text{685})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full cost of wall mounted occupancy sensor</td>
<td>$51</td>
</tr>
<tr>
<td>Full cost of ceiling or remote mounted occupancy sensor</td>
<td>$102</td>
</tr>
<tr>
<td>Full cost of fixture-mounted occupancy sensor</td>
<td>$91.83</td>
</tr>
<tr>
<td>Full cost of fixture embedded occupancy sensor(^\text{686})</td>
<td>$54</td>
</tr>
</tbody>
</table>

\(^{684}\) DEER 2008

\(^{685}\) Taken from NEEP Commercial Lighting Controls, Incremental Cost Data Analysis, 2011 “NEEP Commercial Lighting Controls 2011_08_29.xlsx”

\(^{686}\) Fixture embedded Occupancy Sensors are included with the fixture and therefore no additional installation costs are incurred for these sensors. Therefore, it is assumed that the costs associated with Fixture-embedded Occupancy Sensors should not surpass those of the wall mounted due to the similarity in installation.
LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indus. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indus. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indus. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indus. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on location.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \text{KW}_{\text{Controlled}} \times \text{Hours} \times \text{ESF} \times \text{WHF}_e \]

Where:

- \( \text{KW}_{\text{Controlled}} \) = Total lighting load connected to the control in kilowatts. Savings is per control. The total connected load per control should be collected from the customer or the default values presented below used;

<table>
<thead>
<tr>
<th>Lighting Control Type</th>
<th>Default kw controlled&lt;sup&gt;687&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall mounted occupancy sensor (per control)</td>
<td>0.305</td>
</tr>
<tr>
<td>Remote mounted occupancy sensor (per control)</td>
<td>0.517</td>
</tr>
<tr>
<td>Fixture mounted sensor (per fixture)</td>
<td>0.180</td>
</tr>
</tbody>
</table>

- Hours = total operating hours of the controlled lighting circuit before the lighting controls are installed. This number should be collected from the customer. Average hours of use per year are provided in the Reference Table in Section 4.5, Fixture annual operating hours, for each building type if customer specific information is not collected. If unknown building type, use the Miscellaneous value.

<sup>687</sup> Based on EVT control data for Occupancy Sensor Costs 2009-2014.
ESF = Energy Savings factor (represents the percentage reduction to the operating Hours from the non-controlled baseline lighting system).

<table>
<thead>
<tr>
<th>Lighting Control Type</th>
<th>Energy Savings Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall, Ceiling or Fixture-Mounted Occupancy Sensors</td>
<td>24%</td>
</tr>
<tr>
<td>Wall-Mounted Occupancy Sensors configured as “Vacancy Sensors”</td>
<td>31%</td>
</tr>
</tbody>
</table>

WHFw = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is uncooled, the value is 1.0.

**HEATING PENALTY**

If electrically heated building:

\[ \Delta \text{kWh}_{\text{heatpenalty}} = \text{KW}_{\text{controlled}} \times \text{Hours} \times \text{ESF} \times \frac{-1}{\text{IFkWh}} \]

Where:

IFkWh = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta \text{kW} = \text{KW}_{\text{controlled}} \times \text{WHF}_{d} \times (\text{CF}_{\text{baseline}} - \text{CF}_{\text{os}}) \]

Where:

WHFw = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is uncooled WHFw is 1.

CFbaseline = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66

CFos = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type.

**NATURAL GAS ENERGY SAVINGS**

\[ \Delta \text{therms} = \text{KW}_{\text{controlled}} \times \text{Hours} \times \text{ESF} \times \frac{-1}{\text{IFtherms}} \]

Where:


Papamichael, Konstantinos, Bi-Level Switching in Office Spaces, California Lighting Technology Center, February 1, 2010. Note: See Figure 8 on page 10 for relevant study results. The study shows a 30% extra savings above a typical occupancy sensor; 24% * 1.3 = 31%.

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

Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007. Note, the connected load used in the calculation of the CF for occupancy sensor lights includes the average ESF.
IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by building type.

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-LTG-OSLC-V04-160601

REVIEW DEADLINE: 1/1/2021
4.5.11 Solar Light Tubes

**DESCRIPTION**

A tubular skylight which is 10” to 21” in diameter with a prismatic or translucent lens is installed on the roof of a commercial facility. The lens reflects light captured from the roof opening through a highly specular reflective tube down to the mounted fixture height. When in use, a light tube fixture resembles a metal halide fixture. Uses include grocery, school, retail and other single story commercial buildings.

In order that the savings characterized below apply, the electric illumination in the space must be automatically controlled to turn off or down when the tube is providing enough light.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is assumed to be a tubular skylight that concentrates and directs light from the roof to an area inside the facility.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment for this measure is a fixture with comparable luminosity. The specifications for the baseline lamp depend on the size of the Light Tube being installed.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The estimated useful life for a light tube commercial skylight is 10 years.

**DEEMED MEASURE COST**

If available, the actual incremental cost should be used. For analysis purposes, assume an incremental cost for a light tube commercial skylight is $500.

**LOADSHAPE**

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on location.

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = \text{kW}_f \times \text{HOURS} \times \text{WHFe} \]

Where:

\[ \text{kW}_f = \text{Connected load of the fixture the solar tube replaces} \]

\[ ^{692} \text{Equal to the manufacturers standard warranty} \]

\[ ^{693} \text{The savings from solar light tubes are only realized during the sunlight hours. It is therefore appropriate to apply the single shift (8/5) loadshape to this measure.} \]
Size of Tube | Average Lumen output for Chicago Illinois (minimum) | Equivalent fixture | kW |
--- | --- | --- | --- |
21” | 9,775 (4,179) | 50% 3 x 2 32W lamp CFL (207W, 9915 lumens)  50% 4 lamp F32 w/Elec 4’ T8 (114W, 8895 lumens) | 0.161 |
14” | 4,392 (1,887) | 50% 2 42W lamp CFL (94W, 4406 lumens)  50% 2 lamp F32 w/Elec 4’ T8 (59W, 4448 lumens) | 0.077 |
10” | 2,157 (911) | 50% 1 42W lamp CFL (46W, 2203 lumens)  50% 1 lamp F32 w/Elec 4’ T8 (32W, 2224 lumens) | 0.039 |

**HEATING PENALTY**

If electrically heated building:

\[
\Delta kWh_{\text{heatpenalty}} \text{=} kWh_f \times \text{HOURS} \times -IFkWh
\]

Where:

- \( IFkWh \) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \Delta kW_f \times WHFd \times CF
\]

Where:

- \( WHFd \) = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled WHFd is 1.

- \( CF \) = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

**NATURAL GAS SAVINGS**

\[
\Delta \text{Therms} = \Delta kW_f \times \text{HOURS} \times -IFTherms
\]

Where:

---

695 Ibid. The lumen values presented in the kW table represent the average of the lightest 2400 hours.
696 Negative value because this is an increase in heating consumption due to the efficient lighting.
697 Negative value because this is an increase in heating consumption due to the efficient lighting.
IFTherms = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Please select from the Reference Table in Section 4.5 for each building type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-LTG-STUB-V02-140601**

**REVIEW DEADLINE: 1/1/2020**
4.5.12 T5 Fixtures and Lamps

**DESCRIPTION**

T5 Lamp/ballast systems have higher lumens per watt than a standard T8 or an existing T8 or T12 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 or T12 fixtures, while using fewer watts.

This measure applies to the installation of new equipment with efficiencies that exceed that of the equipment that would have been installed following standard market practices and is applicable to time of sale as well as retrofit measures.

If the implementation strategy does not allow for the installation location to be known, a deemed split of 99% Commercial and 1% Residential should be used.

This measure was developed to be applicable to the following program types: TOS, RF, DI.

If applied to other program types, the measure savings should be verified.

The measure applies to all commercial T5 installations excluding new construction and substantial renovation or change of use measures (see lighting power density measure). Lookup tables have been provided to account for various installations. Actual existing equipment wattages should be compared to new fixture wattages whenever possible while maintaining lumen equivalent designs. Default new and baseline assumptions are provided if existing equipment cannot be determined. Actual costs and hours of use should be utilized when available. Default component costs and lifetimes have been provided for Operating and Maintenance Calculations. Please see the Definition Table to determine applicability for each program. Configurations not included in the TRM may be included in custom program design using the provided algorithms as long as energy savings is achieved. The following table defines the applicability for different programs:

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and DI</th>
</tr>
</thead>
<tbody>
<tr>
<td>This program applies to installations where customer and location of equipment is not known, or at time of burnout of existing equipment. T5 Lamp/ballast systems have higher lumens per watt than a standard T8 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 fixtures, while using fewer watts.</td>
<td>For installations that upgrade installations before the end of their useful life. T5 Lamp/ballast systems have higher lumens per watt than a standard T8 or T12 system. The smaller lamp diameter allows for better optical systems, and more precise control of lighting. These characteristics result in light fixtures that produce equal or greater light than standard T8 or T12 fixtures, while using fewer watts and having longer life.</td>
</tr>
</tbody>
</table>

**DEFINITION OF EFFICIENT EQUIPMENT**

The definition of efficient equipment varies based on the program and is defined below:

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and DI</th>
</tr>
</thead>
<tbody>
<tr>
<td>4' fixtures must use a T5 lamp and ballast configuration. 1' and 3' lamps are not eligible. High Performance Troffers must be 85% efficient or greater. T5 HO high bay fixtures must be 3, 4 or 6 lamps and 90% efficient or better.</td>
<td>4' fixtures must use a T5 lamp and ballast configuration. 1' and 3' lamps are not eligible. High Performance Troffers must be 85% efficient or greater. T5 HO high bay fixtures must be 3, 4 or 6 lamps and 90% efficient or better.</td>
</tr>
</tbody>
</table>

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698 Based on weighted average of Final ComEd’s BILD program data from PY5 and PY6. For Residential installations, hours of use assumptions from ‘5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture’ measure should be used.
**DEFINITION OF BASELINE EQUIPMENT**

The definition of baseline equipment varies based on the program and is defined below:

<table>
<thead>
<tr>
<th>Time of Sale (TOS)</th>
<th>Retrofit (RF) and DI</th>
</tr>
</thead>
<tbody>
<tr>
<td>The baseline is T8 with equivalent lumen output. In high-bay applications, the baseline is pulse start metal halide systems.</td>
<td>The baseline is the existing system. In July 14, 2012, Federal Standards were enacted that were expected to eliminate T-12s as an option for linear fluorescent fixtures. Through v3.0 of the TRM, it was assumed that the T-12 would no longer be baseline for retrofits from 1/1/2016. However, due to significant loopholes in the legislation, T-12 compliant product is still freely available and in Illinois T-12s continue to hold a significant share of the existing and replacement lamp market. Therefore the timing of the sunsetting of T-12s as a viable baseline has been pushed back in v6.0 until 1/1/2019 and will be revisited in future update sessions. There will be a baseline shift applied to all measures installed before 2019 in years remaining in the measure life. See table C-1.</td>
</tr>
</tbody>
</table>

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The deemed lifetime of the efficient equipment fixture, regardless of program type is Fixture lifetime is 15 years

**LOADSHAPE**

- Loadshape C06 - Commercial Indoor Lighting
- Loadshape C07 - Grocery/Conv. Store Indoor Lighting
- Loadshape C08 - Hospital Indoor Lighting
- Loadshape C09 - Office Indoor Lighting
- Loadshape C10 - Restaurant Indoor Lighting
- Loadshape C11 - Retail Indoor Lighting
- Loadshape C12 - Warehouse Indoor Lighting
- Loadshape C13 - K-12 School Indoor Lighting
- Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
- Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
- Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
- Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
- Loadshape C18 - Industrial Indoor Lighting
- Loadshape C19 - Industrial Outdoor Lighting
- Loadshape C20 - Commercial Outdoor Lighting

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699 15 years from GDS Measure Life Report, June 2007
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \frac{(\text{Watts}_{\text{base}} - \text{Watts}_{\text{EE}})}{1000} \times \text{Hours} \times \text{WHF}_e \times \text{ISR} \]

Where:

- \( \text{Watts}_{\text{base}} \) = Input wattage of the existing system which depends on the baseline fixture configuration (number and type of lamp) and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the existing system.

- \( \text{Watts}_{\text{EE}} \) = New input wattage of EE fixture which depends on new fixture configuration (number of lamps) and ballast factor and number of fixtures. Value can be selected from the appropriate reference table as shown below, of a custom value can be entered if the configurations in the tables is not representative of the existing system.

- \( \text{WHF}_e \) = Waste heat factor for energy to account for cooling energy savings from efficient lighting is selected from the Reference Table in Section 4.5 for each building type. If building is un-cooled, the value is 1.0.

- \( \text{ISR} \) = In Service Rate or the percentage of units rebated that get installed. = 100\%\(^700\) if application form completed with sign off that equipment is not placed into storage. If sign off form not completed assume the following 3 year ISR assumptions:

<table>
<thead>
<tr>
<th>Program</th>
<th>Reference Table</th>
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<tbody>
<tr>
<td>Time of Sale</td>
<td>A-1: T5 New and Baseline Assumptions</td>
</tr>
<tr>
<td>Retrofit, DI</td>
<td>A-2: T5 New and Baseline Assumptions</td>
</tr>
</tbody>
</table>

- \( \text{Hours} \) = Average hours of use per year as provided by the customer or selected from the Reference Table in Section 4.5, Fixture annual operating hours, by building type. If hours or building type are unknown, use the Miscellaneous value.

- \( \text{ISR} \) = In Service Rate or the percentage of units rebated that get installed.

\(^700\) Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an “In-Service Rate” when commercial customers complete an application form.

\(^701\) 1st year in service rate is based upon review of PY5-6 evaluations from ComEd’s commercial lighting program (BILD) (see ‘IL Commercial Lighting ISR_2014.xls’ for more information)

\(^702\) The 98% Lifetime ISR assumption is based upon review of two evaluations:

- ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report; Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

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**HEATING PENALTY**

If electrically heated building:

\[ \Delta k\text{Wh}_{\text{heat penalty}} = \left(\frac{(\text{WattsBase} - \text{WattsEE})}{1000}\right) \times \text{ISR} \times \text{Hours} \times -\text{IFkWh} \]

Where:

- \( \text{IFkWh} \) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT DEMAND SAVINGS**

\[ \Delta kW = \left(\frac{(\text{Wattsbase} - \text{WattsEE})}{1000}\right) \times \text{WHF}_d \times \text{CF} \times \text{ISR} \]

Where:

- \( \text{WHF}_d \) = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is selected from the Reference Table in Section 4.5 for each building type. If the building is not cooled \( \text{WHF}_d \) is 1.
- \( \text{CF} \) = Summer Peak Coincidence Factor for measure is selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value.

**NATURAL GAS ENERGY SAVINGS**

\[ \Delta \text{Therms} = \left(\frac{(\text{WattsBase} - \text{WattsEE})}{1000}\right) \times \text{ISR} \times \text{Hours} \times -\text{IFTherms} \]

Where:

- \( \text{IFTherms} \) = Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. This value is selected from the Reference Table in Section 4.5 for each building type.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

See Reference tables for Operating and Maintenance Values

<table>
<thead>
<tr>
<th>Program</th>
<th>Reference Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>B-1: T5 Component Costs and Lifetime</td>
</tr>
<tr>
<td>Retrofit, DI</td>
<td>B-2: T5 Component Costs and Lifetime</td>
</tr>
</tbody>
</table>

**REFERENCE TABLES**

See following page.

---

\(^{703}\)Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{704}\)Negative value because this is an increase in heating consumption due to the efficient lighting.
## A-1: Time of Sale: T5 New and Baseline Assumptions

<table>
<thead>
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<th>EE Measure Description</th>
<th>EE Cost</th>
<th>Watts&lt;sub&gt;EE&lt;/sub&gt;</th>
<th>Baseline Description</th>
<th>Base Cost</th>
<th>Watts&lt;sub&gt;BASE&lt;/sub&gt;</th>
<th>Measure Cost</th>
<th>Watts&lt;sub&gt;SAVE&lt;/sub&gt;</th>
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<td>200 Watt Pulse Start Metal-Halide</td>
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### Retrofit T5 New and Baseline Assumptions

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<tr>
<td>1-Lamp T5 Industrial/Strip</td>
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706 Ibid.
### B-1: Time of Sale T5 Component Costs and Lifetime

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<td>3-Lamp T5 High-Bay</td>
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<td><strong>$15.00</strong></td>
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### B-2: T5 Retrofit Component Costs and Lifetime

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C-1: T12 Baseline Adjustment:

Savings Adjustment Factors

<table>
<thead>
<tr>
<th>Measure Code</th>
<th>Equivalent T12 watts adjusted for lumen equivalence 38 w and 40 w with EEMag ballast</th>
<th>Equivalent T12 watts adjusted for lumen equivalence 40 w with EEMag ballast</th>
<th>Equivalent T12 watts adjusted for lumen equivalence 40 w with Mag ballast</th>
<th>Proportionally Adjusted for Lumens wattage for T8 equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Lamp T5 Industrial/Strip</td>
<td>32</td>
<td>61</td>
<td>73</td>
<td>82</td>
</tr>
<tr>
<td>2-Lamp T5 Industrial/Strip</td>
<td>64</td>
<td>103</td>
<td>125</td>
<td>135</td>
</tr>
<tr>
<td>3-Lamp T5 Industrial/Strip</td>
<td>96</td>
<td>167</td>
<td>185</td>
<td>211</td>
</tr>
<tr>
<td>4-Lamp T5 Industrial/Strip</td>
<td>128</td>
<td>211</td>
<td>249</td>
<td>226</td>
</tr>
</tbody>
</table>

Measures installed in 2018 will claim full savings for one year. Savings adjustment factors based on a T8 baseline will be applied to the full savings for savings starting in 2019 and for the remainder of the measure life. The adjustment to be applied for each measure is listed in the reference table above and is based on equivalent lumens.

**Measure Code:** CI-LTG-T5FX-V05-180101

**Review Deadline:** 1/1/2019
4.5.13 Occupancy Controlled Bi-Level Lighting Fixtures

**DESCRIPTION**

This measure relates to replacing existing uncontrolled continuous lighting fixtures with new bi-level lighting fixtures. This measure can only relate to replacement in an existing building, since multi-level switching is required in the Commercial new construction building energy code (IECC 2012/2015).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient system is assumed to be an occupancy controlled lighting fixture that reduces light level during unoccupied periods.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be an uncontrolled lighting system on continuously, e.g. in stairwells and corridors for health and safety reasons.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life for all lighting controls is assumed to be 8 years\(^{709}\).

**DEEMED MEASURE COST**

When available, the actual cost of the measure shall be used. When not available, the assumed measure cost is $274\(^{710}\).

**LOADSHAPE**

- Loadshape C06 - Commercial Indoor Lighting
- Loadshape C07 - Grocery/Conv. Store Indoor Lighting
- Loadshape C08 - Hospital Indoor Lighting
- Loadshape C09 - Office Indoor Lighting
- Loadshape C10 - Restaurant Indoor Lighting
- Loadshape C11 - Retail Indoor Lighting
- Loadshape C12 - Warehouse Indoor Lighting
- Loadshape C13 - K-12 School Indoor Lighting
- Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
- Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
- Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
- Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
- Loadshape C18 - Industrial Indoor Lighting
- Loadshape C19 - Industrial Outdoor Lighting
- Loadshape C20 - Commercial Outdoor Lighting

\(^{709}\) DEER 2008.

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section below.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta k\text{Wh} = (K_{\text{Baseline}} - (K_{\text{Controlled}} \times (1 - \text{ESF}))) \times \text{Hours} \times WHF_e \]

Where:

- \( K_{\text{Baseline}} \) = Total baseline lighting load of the existing/baseline fixture
  = Actual
  Note that if the existing fixture is only being retrofit with bi-level occupancy controls and not being replaced, \( K_{\text{Baseline}} \) will equal \( K_{\text{Controlled}} \).

- \( K_{\text{Controlled}} \) = Total controlled lighting load at full light output of the new bi-level fixture
  = Actual

- Hours = Number of hours lighting is on. This measure is limited to 24/7 operation.
  = 8,766

- ESF = Energy Savings factor (represents the percentage reduction to the \( K_{\text{Controlled}} \) due to the occupancy control).

\[ \text{ESF} = \% \text{ Standby Mode} \times (1 - \% \text{ Full Light at Standby Mode}) \]

- \% Standby Mode = Represents the percentage of the time the fixture is operating in standby (i.e. low-wattage) mode.

- \% Full Light at Standby Mode = Represents the assumed wattage consumption during standby mode relative to the full wattage consumption. Can be achieved either through dimming or a stepped control strategy.

- WHF_e = Dependent on application. If participant provided or metered data is available for both or either of these inputs a custom savings factor should be calculated. If not defaults are provided below:

<table>
<thead>
<tr>
<th>Application</th>
<th>% Standby Mode</th>
<th>% Full Light at Standby Mode</th>
<th>Energy Savings Factor (ESF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stairwells</td>
<td>78.5%(^{711})</td>
<td>50%</td>
<td>39.3%</td>
</tr>
<tr>
<td></td>
<td>33%</td>
<td>52.6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>70.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5%</td>
<td>74.6%</td>
<td></td>
</tr>
<tr>
<td>Corridors</td>
<td>50%</td>
<td>25.0%</td>
<td></td>
</tr>
</tbody>
</table>

\(^{711}\) Average found from the four buildings in the State of California Energy Commission Lighting Research Program Bi-Level Stairwell Fixture Performance Final Report:

http://www.archenergy.com/lrp/lightingperf_standards/project_5_1_reports.htm
<table>
<thead>
<tr>
<th>Application</th>
<th>% Standby Mode</th>
<th>% Full Light at Standby Mode</th>
<th>Energy Savings Factor (ESF)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50.0%(^{712})</td>
<td>33%</td>
<td>33.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>45.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>47.5%</td>
</tr>
<tr>
<td>Other 24/7 Space Type</td>
<td>50.0%(^{713})</td>
<td>33%</td>
<td>33.5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
<td>45.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5%</td>
<td>47.5%</td>
</tr>
</tbody>
</table>

\(\text{WHF}_e\) = Waste heat factor for energy to account for cooling energy savings from efficient lighting is provided in the Reference Table in Section 4.5 for each building type. If building is uncooled, the value is 1.0.

**HEATING PENALTY**

If electrically heated building:

\[
\Delta \text{kWh}_{\text{heating penalty}}^{714} = (\text{KW}_{\text{Baseline}} - (\text{KW}_{\text{Controlled}} * (1 - \text{ESF}))) * \text{Hours} * -\text{IFkWh}
\]

Where:

\(\text{IFkWh}\) = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta \text{kW} = (\text{KW}_{\text{Baseline}} - (\text{KW}_{\text{Controlled}} * (1 - \text{ESF}))) * \text{WHF}_d * (\text{CF}_{\text{baseline}} - \text{CF}_{\text{os}})
\]

Where:

\(\text{WHF}_d\) = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If the building is uncooled \(\text{WHF}_d\) is 1.

\(\text{CF}_{\text{baseline}}\) = Baseline Summer Peak Coincidence Factor for the lighting system without Occupancy Sensors installed selected from the Reference Table in Section 4.5 for each building type. If the building type is unknown, use the Miscellaneous value of 0.66.

\(\text{CF}_{\text{os}}\) = Retrofit Summer Peak Coincidence Factor the lighting system with Occupancy Sensors installed is 0.15 regardless of building type\(^{715}\).

\(^{712}\) Value determined from the Pacific Gas and Electric Company: Bi-Level Lighting Control Credits study for Interior Corridors of Hotels, Motels and High Rise Residential.


\(^{713}\) Conservative estimate.

\(^{714}\) Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{715}\) Coincidence Factor Study Residential and Commercial Industrial Lighting Measures, RLW Analytics, Spring 2007. Note, the connected load used in the calculation of the CF for occupancy sensor lights includes the average ESF.
NATURAL GAS HEATING PENALTY

If natural gas heating:

\[ \Delta \text{therms} = (\text{KW}_{\text{Baseline}} - (\text{KW}_{\text{Controlled}} \times (1 - \text{ESF}))) \times \text{Hours} \times \text{IFTherms} \]

Where:

\[ \text{IFTherms} = \text{Lighting-HVAC Integration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting and provided in the Reference Table in Section 4.5 by building type.} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-OCBL-V02-160601

REVIEW DEADLINE: 1/1/2021
4.5.14 Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

DESCRIPTION

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb in a commercial location.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

If the implementation strategy does not allow for the installation location to be known a deemed split should be used. For Residential targeted programs (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used\(^\text{716}\), and for Commercial targeted programs a deemed split of 4% Residential and 96% Commercial should be used\(^\text{717}\).

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a qualified specialty compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5” diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps >60W) and intermediate base lamps (>40W).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) should be calculated by dividing the rated life of the bulb (10,000 hours\(^\text{718}\)) by the run hours. For example using Miscellaneous at 3612 hours would give 2.8 years. For non-exempt bulbs, when the number of years exceeds 2021, the number of years to that date should be used.

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5\(^\text{719}\).

For the Retrofit measures, the full cost of $8.50 should be used plus $5 labor\(^\text{720}\) for a total of $13.50. However actual program delivery costs should be utilized if available.

\(^{716}\) RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See ‘RESvCI Split_112015.xls’.

\(^{717}\) Based upon final weighted (by sales volume) average of the BILD program (ComEd’s commercial lighting program) for PY 4 and PY5 and PY6.

\(^{718}\) Energy Star bulbs have a rated life of at least 8000 hours. In commercial settings you expect significantly less on/off switching than residential and so a rated life assumption of 10,000 hours is used.

\(^{719}\) NEEP Residential Lighting Survey, 2011

\(^{720}\) Based on 15 minutes at $20 per hour.
LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indist. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indist. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indist. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indist. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in section 4.5.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{WHFe} \]

Where:

\( \text{WattsBase} \) = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain the incandescent bulb equivalent wattage\(^{721}\); use 60W if unknown\(^{722}\)

EISA exempt bulb types:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Spirals &gt;=2601</td>
<td>2601</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>5279</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>5280</td>
<td>6209</td>
<td>300</td>
</tr>
</tbody>
</table>


### Commercial ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3-Way</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe</td>
<td>90</td>
<td>179</td>
<td>10</td>
</tr>
<tr>
<td>(medium and intermediate bases less than 750 lumens)</td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td>Decorative</td>
<td>70</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td>(Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)</td>
<td>90</td>
<td>149</td>
<td>15</td>
</tr>
<tr>
<td>Globe</td>
<td>90</td>
<td>179</td>
<td>10</td>
</tr>
<tr>
<td>(candelabra bases less than 1050 lumens)</td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td>Decorative</td>
<td>70</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td>(Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)</td>
<td>90</td>
<td>149</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EISA non-exempt bulb types:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bulb Type</strong></td>
</tr>
<tr>
<td>Dimmable Twist, Globe (less than 5” in diameter and &gt; 749 lumens), candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt;1049 lumens), Intermediate Base Lamps (&gt;749 lumens)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
**Directional Lamps** - ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20W and 50 Lm/W for lamps with rated wattages >= 20 watts\(^{723}\).

For Directional R, BR, and ER lamp types\(^{724}\):

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>420</td>
<td>472</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>473</td>
<td>524</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>525</td>
<td>714</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>715</td>
<td>937</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>938</td>
<td>1259</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>1260</td>
<td>1399</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td>1739</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>1740</td>
<td>2174</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>2175</td>
<td>2624</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>2625</td>
<td>2999</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>4500</td>
<td>200</td>
</tr>
<tr>
<td>*R, BR, and ER with medium screw bases w/ diameter &lt;=2.25&quot;</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>499</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>649</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>1199</td>
<td>65</td>
</tr>
<tr>
<td>*ER30, BR30, BR40, or ER40</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>499</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>649</td>
<td>50</td>
</tr>
<tr>
<td>*BR30, BR40, or ER40</td>
<td>650</td>
<td>1419</td>
<td>65</td>
</tr>
<tr>
<td>*R20</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>719</td>
<td>45</td>
</tr>
<tr>
<td>*All reflector lamps below lumen ranges specified above</td>
<td>200</td>
<td>299</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>399</td>
<td>30</td>
</tr>
</tbody>
</table>

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.\(^{725}\)

---

\(^{723}\) From pg 10 of the Energy Star Specification for lamps v1.1

\(^{724}\) From pg 11 of the Energy Star Specification for lamps v1.1

available or if the equation below returns a negative value (or undefined), use the manufacturer’s recommended baseline wattage equivalent.

\[
\text{Watts}_{\text{base}} = 375.1 - 4.355(D) - \sqrt{227,800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D + BA) + 14.69(BA^2) - 16,720 \cdot \ln(CBCP)}
\]

Where:

- \( D \) = Bulb diameter (e.g. for PAR20 \( D = 20 \))
- \( BA \) = Beam angle
- \( CBCP \) = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Permitted Wattages</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>20, 35, 40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>30S</td>
<td>40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>30L</td>
<td>50, 75</td>
</tr>
<tr>
<td>38</td>
<td>40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250</td>
</tr>
</tbody>
</table>

EISA non-exempt bulb types:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Incandescent Equivalent Post-EISA 2007 (WattsBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimmable Twist, Globe (less than 5&quot; in diameter and &gt; 749 lumens), candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt;1049 lumens), Intermediate Base Lamps (&gt;749 lumens)</td>
<td>310 749</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>750 1049</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1050 1489</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1490 2600</td>
<td>72</td>
<td></td>
</tr>
</tbody>
</table>

\( \text{Watts}_{\text{EE}} \) = Actual wattage of energy efficient specialty bulb purchased, use 15W if unknown

\( \text{ISR} \) = In Service Rate or the percentage of units rebated that get installed.

\( \text{i}100\% \) if application form completed with sign off that equipment is not placed into storage

---

\(^{226}\) The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.


\(^{228}\) Illinois evaluation of PY1 through PY3 has not found that fixtures or lamps placed into storage to be a significant enough issue to warrant including an “In-Service Rate” when commercial customers complete an application form.
If sign off form not completed assume the following 3 year ISR assumptions:

<table>
<thead>
<tr>
<th>Weigted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>71.2%(^{729})</td>
<td>14.5%</td>
<td>12.3%</td>
<td>98.0%(^{730})</td>
</tr>
</tbody>
</table>

Hours = Average hours of use per year are provided in Reference Table in Section 4.5, Screw based bulb annual operating hours, for each building type\(^{731}\). If unknown use the Miscellaneous value.

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.
- Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.
  - The NTG factor for the Purchase Year should be applied.

EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

\[ \Delta kWh = \left( \frac{(45 - 14)}{1000} \right) \times 1.0 \times 3088 \times 1.25 \]
\[ = 119.7 \text{ kWh} \]

HEATING PENALTY

If electrically heated building:

\(^{729}\) 1st year in service rate is based upon review of PY4-6 evaluations from ComEd’s commercial lighting program (BILD) (see ‘IL Commercial Lighting ISR_2014.xls’ for more information. The average first year ISR was calculated weighted by the number of bulbs sold.

\(^{730}\) The 98% Lifetime ISR assumption is based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings. Note that this Final Install Rate does NOT account for leakage of purchased bulbs being installed outside of the utility territory. EM&V should assess how and if data from evaluation should adjust this final installation rate to account for this impact.

\(^{731}\) Based on ComEd analysis taking DEER 2008 values and averaging with PY1 and PY2 evaluation results.
\[ \Delta \text{kWh}_{\text{heatpenalty}} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{IFkWh} \]

Where:

- \text{IFkWh} = Lighting-HVAC Interation Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

### EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in a heat pump heated office and sign off form provided.

\[
\Delta \text{kWh}_{\text{heatpenalty}} = \left( \frac{(45 - 14)}{1000} \right) \times 1.0 \times 3088 \times -0.183 \\
= -17.5 \text{kWh}
\]

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[ \Delta \text{kW} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{WHFd} \times \text{CF} \]

Where:

- \text{WHFd} = Waste heat factor for demand to account for cooling savings from efficient lighting in cooled buildings is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.
- \text{CF} = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

### EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in an office and sign off form provided.

\[
\Delta \text{kW} = \left( \frac{(45 - 14)}{1000} \right) \times 1.0 \times 1.3 \times 0.66 \\
= 0.027 \text{kW}
\]

### NATURAL GAS SAVINGS

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

\[ \Delta \text{Therms} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{-IFTherms} \]

Where:

- \text{IFTherms} = Negative value because this is an increase in heating consumption due to the efficient lighting.

---

\[732\text{Negative value because this is an increase in heating consumption due to the efficient lighting.}\]

\[733\text{Negative value because this is an increase in heating consumption due to the efficient lighting.}\]
IFTherms = Lighting-HVAC Iteration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

EXAMPLE

For example, for a 14W 500 lumen R20 reflector lamp is installed in a gas heated office and sign off form provided.

\[
\Delta \text{Therms} = ((45 - 14)/1000) * 1.0 * 3088 * 0.016
\]

\[
\Delta \text{Therms} = 1.5 \text{ Therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be (1000/HOURS) year; baseline replacement cost is assumed to be $3.5 for those bulbs types exempt from EISA and $5 for non-exempt EISA bulb types defined above. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: CI-LTG-SCFL-V03-180101**

**REVIEW DEADLINE: 1/1/2020**

---

\(^{734}\)NEEP Residential Lighting Survey, 2011
4.5.15 LED Open Sign

DESCRIPTION

LED open signs must replace an existing neon open sign. LED drivers can be either electronic switching or linear magnetic, with the electronic switching supplies being the most efficient. The on/off power switch may be found on either the power line or load side of the driver, with the line side location providing significantly lower standby losses when the sign is turned off and is not operating. All new open signs must meet UL-84 (UL-844) requirements.

Replacement signs cannot use more than 20% of the input power of the sign that is being replaced.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient product is an LED type illuminated open sign.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a neon type illuminated open sign.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life is 15 years. 735

DEEMED MEASURE COST

The actual measure installation cost should be used (including material and labor).

LOADSHAPE

Loadshape C06 - Commercial Indoor Lighting
Loadshape C07 - Grocery/Conv. Store Indoor Lighting
Loadshape C08 - Hospital Indoor Lighting
Loadshape C09 - Office Indoor Lighting
Loadshape C10 - Restaurant Indoor Lighting
Loadshape C11 - Retail Indoor Lighting
Loadshape C12 - Warehouse Indoor Lighting
Loadshape C13 - K-12 School Indoor Lighting
Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)
Loadshape C18 - Industrial Indoor Lighting
Loadshape C19 - Industrial Outdoor Lighting
Loadshape C20 - Commercial Outdoor Lighting

735 15 years from GDS Measure Life Report, June 2007
**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is dependent on the location type. Values are provided for each building type in the reference section in Section 4.5.

---

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

The following equation was used to determine the energy savings from installing LED open signs:

\[
\Delta \text{kWh} = \frac{(\text{Watts}_{\text{base}} - \text{Watts}_{\text{ee}})}{1,000} \times \text{Hours} \times \text{WHFe}
\]

Where:
- **Watts\text{base}** = Wattage of neon sign with magnetic high voltage transformer
  - Actual; if unknown use 46.0W\(^{736}\)
- **Watts\text{ee}** = Wattage of LED sign with low voltage transformer
  - Actual; if unknown use 14.9W\(^{737}\)
- **Hours** = Annual hours of operation, assumed to be consistent with operating hours. Values are provided in the Reference Table in Section 4.5.
- **WHFe** = Waste heat factor for energy to account for cooling energy savings from efficient lighting are provided below for each building type in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**HEATING PENALTY**

If electrically heated building:

\[
\Delta \text{kWh}_{\text{heatpenalty}} = \frac{(\text{Watts}_{\text{base}} - \text{Watts}_{\text{ee}})}{1000} \times \text{Hours} \times \text{-IFkWh}
\]

Where:
- **IFkWh** = Lighting-HVAC Iteration Factor for electric heating impacts; this factor represents the increased electric space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

**DEMAND SAVINGS**

\[
\Delta \text{kW} = \frac{(\text{Watts}_{\text{base}} - \text{Watts}_{\text{ee}})}{1000} \times \text{CF} \times \text{WHFd}
\]

Where:
- **WHFd** = Waste Heat Factor for Demand to account for cooling savings from efficient lighting in cooled buildings is provided in Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

\(^{736}\) Measured average demand data. Southern California Edison, “Replace Neon Open Sign with LED Open Sign”, Workpaper SCE13LG070, Revision 2, October 2015. Pg. 10

\(^{737}\) Ibid.

\(^{738}\) Negative value because this is an increase in heating consumption due to the efficient lighting.
CF = Summer Peak Coincidence Factor for measure is provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other variables as provided above.

Based on defaults provided above, the deemed energy savings are provided below:

### Electric Energy and Coincident Peak Demand Savings

<table>
<thead>
<tr>
<th>Building Types</th>
<th>Energy Savings (kWh)</th>
<th>ΔkWh&lt;sub&gt;heatpenalty&lt;/sub&gt; (if electric heat)</th>
<th>Coincident Demand Savings (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience Store</td>
<td>158</td>
<td>-120</td>
<td>0.0298</td>
</tr>
<tr>
<td>Grocery</td>
<td>152</td>
<td>-74</td>
<td>0.0277</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>169</td>
<td>-17</td>
<td>0.0374</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>229</td>
<td>-143</td>
<td>0.0282</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>121</td>
<td>-73</td>
<td>0.0227</td>
</tr>
<tr>
<td>Restaurant</td>
<td>203</td>
<td>-85</td>
<td>0.0277</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>191</td>
<td>-88</td>
<td>0.0387</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>115</td>
<td>-55</td>
<td>0.0245</td>
</tr>
</tbody>
</table>

### Natural Gas Savings

Heating Penalty if fossil fuel heated building (or if heating fuel is unknown):

$$\Delta \text{Therms} = \frac{\langle \text{WattsBase} - \text{WattsEE} \rangle}{1000} \cdot \text{Hours} \cdot \text{IFTerms}$$

Where:

IFTerms = Lighting-HVAC Iteration Factor for gas heating impacts; this factor represents the increased gas space heating requirements due to the reduction of waste heat rejected by the efficient lighting. Values are provided in the Reference Table in Section 4.5. If unknown, use the Miscellaneous value.

Other factors as defined above

Based on defaults provided above, the deemed penalty is provided below:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>ΔTherms&lt;sub&gt;heatpenalty&lt;/sub&gt; (if gas heat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convenience Store</td>
<td>-5.1</td>
</tr>
<tr>
<td>Grocery</td>
<td>-3.2</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>-0.7</td>
</tr>
<tr>
<td>Hotel/Motel - Common</td>
<td>-6.1</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>-3.2</td>
</tr>
<tr>
<td>Restaurant</td>
<td>-3.6</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>-3.7</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>-2.3</td>
</tr>
</tbody>
</table>

### Water and Other Non-Energy Impact Descriptions and Calculation

N/A

---

739 Savings can be calculated for additional building types using the default values provided in the Reference Table in Section 4.5.

740 Negative value because this is an increase in heating consumption due to the efficient lighting.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-LTG-OPEN-V01-180101

REVIEW DEADLINE: 1/1/2022
4.6 Refrigeration End Use

4.6.1 Automatic Door Closer for Walk-In Coolers and Freezers

**DESCRIPTION**

This measure is for installing an auto-closer to the main insulated opaque door(s) of a walk-in cooler or freezer. The auto-closer must firmly close the door when it is within 1 inch of full closure.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

This measure consists of the installation of an automatic, hydraulic-type door closer on main walk-in cooler or freezer doors. These closers save energy by reducing the infiltration of warm outside air into the refrigeration itself.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline condition is assumed to be a walk in cooler or freezer without an automatic closure.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The deemed measure life is 8 years.\(^{741}\)

**DEEMED MEASURE COST**

The deemed measure cost is $156.82 for a walk-in cooler or freezer.\(^{742}\)

**LOADSHAPE**

Loadshape C22 - Commercial Refrigeration

**COINCIDENCE FACTOR**

The measure has deemed kW savings therefore a coincidence factor does not apply.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Savings calculations are based on values from through PG&E’s Workpaper PGECOREF110.1 – Auto-Closers for Main Cooler or Freezer Doors. Savings are averaged across all California climate zones and vintages\(^ {743}\).

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk in Cooler</td>
<td>943</td>
</tr>
<tr>
<td>Walk in Freezer</td>
<td>2307</td>
</tr>
</tbody>
</table>

---

\(^{741}\) Source: DEER 2008

\(^{742}\) Ibid.

\(^{743}\) Measure savings from ComEd TRM developed by KEMA. June 1, 2010
SUMMER COINCIDENT PEAK DEMAND SAVINGS

<table>
<thead>
<tr>
<th>Annual Savings</th>
<th>kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk in Cooler</td>
<td>0.137</td>
</tr>
<tr>
<td>Walk in Freezer</td>
<td>0.309</td>
</tr>
</tbody>
</table>

NATURAL GAS ENERGY SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-RFG-ATDC-V01-120601

REVIEW DEADLINE: 1/1/2019
4.6.2 Beverage and Snack Machine Controls

DESCRIPTION
This measure relates to the installation of new controls on refrigerated beverage vending machines, non-refrigerated snack vending machines, and glass front refrigerated coolers. Controls can significantly reduce the energy consumption of vending machine and refrigeration systems. Qualifying controls must power down these systems during periods of inactivity but, in the case of refrigerated machines, must always maintain a cool product that meets customer expectations. This measure relates to the installation of a new control on a new or existing unit. This measure should not be applied to ENERGY STAR qualified vending machines, as they already have built-in controls.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
In order for this characterization to apply, the efficient equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler with a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

DEFINITION OF BASELINE EQUIPMENT
In order for this characterization to apply, the baseline equipment is assumed to be a standard efficiency refrigerated beverage vending machine, non-refrigerated snack vending machine, or glass front refrigerated cooler without a control system capable of powering down lighting and refrigeration systems during periods of inactivity.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 5 years.  

DEEMED MEASURE COST
The actual measure installation cost should be used (including material and labor), but the following can be assumed for analysis purposes:

- Refrigerated Vending Machine and Glass Front Cooler: $180.00
- Non-Refrigerated Vending Machine: $80.00

LOADSHAPE
Loadshape C52 - Beverage and Snack Machine Controls

COINCIDENCE FACTOR
The summer peak coincidence factor for this measure is assumed to be 0.

---

745 ComEd workpapers, 8—15-11.pdf
746 Assumed that the peak period is coincident with periods of high traffic diminishing the demand reduction potential of occupancy based controls.
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \text{WATTSSbase} / 1000 \times \text{HOURS} \times \text{ESF} \]

Where:

- **WATTSSbase** = connected W of the controlled equipment; see table below for default values by connected equipment type:

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>WATTSSbase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerated Beverage Vending Machines</td>
<td>400</td>
</tr>
<tr>
<td>Non-Refrigerated Snack Vending Machines</td>
<td>85</td>
</tr>
<tr>
<td>Glass Front Refrigerated Coolers</td>
<td>460</td>
</tr>
</tbody>
</table>

1000 = conversion factor (W/kW)

HOURS = operating hours of the connected equipment; assumed that the equipment operates 24 hours per day, 365.25 days per year

\[ \text{HOURS} = 24 \times 365.25 = 8766 \]

ESF = Energy Savings Factor; represents the percent reduction in annual kWh consumption of the equipment controlled; see table below for default values:

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Energy Savings Factor (ESF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refrigerated Beverage Vending Machines</td>
<td>46%</td>
</tr>
<tr>
<td>Non-Refrigerated Snack Vending Machines</td>
<td>46%</td>
</tr>
<tr>
<td>Glass Front Refrigerated Coolers</td>
<td>30%</td>
</tr>
</tbody>
</table>

EXAMPLE

For example, adding controls to a refrigerated beverage vending machine:

\[ \Delta \text{kWh} = \text{WATTSSbase} / 1000 \times \text{HOURS} \times \text{ESF} \]

\[ = 400 / 1000 \times 8766 \times 0.46 \]

\[ = 1613 \text{kWh} \]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

---


748 Ibid.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-RFG-BEVM-V02-150601

REVIEW DEADLINE: 1/1/2019
4.6.3 Door Heater Controls for Cooler or Freezer

**DESCRIPTION**

By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize significant energy savings. There are two commercially available control strategies that achieve “on-off” control of door heaters based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is assumed to be a door heater control on a commercial glass door cooler or refrigerator utilizing humidity or conductivity control.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline condition is assumed to be a commercial glass door cooler or refrigerator with a standard heated door with no controls installed.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years.<sup>749</sup>

**DEEMED MEASURE COST**

The incremental capital cost for a humidity-based control is $300 per circuit regardless of the number of doors controlled. The incremental cost for conductivity-based controls is $200.<sup>750</sup>

**LOADSHAPE**

Loadshape C51 - Door Heater Control

**COINCIDENCE FACTOR<sup>751</sup>**

The summer peak coincidence factor for this measure is assumed to be 0%.<sup>752</sup>

---


<sup>751</sup> Source partial list from DEER 2008

<sup>752</sup> Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings from door heater controls.
Algorithm

**Calculation of Savings**

**Electric Energy Savings**

\[ \Delta k\text{WH} = kW_{\text{base}} \times \text{NUMdoors} \times \text{ESF} \times \text{BF} \times 8766 \]

Where:

- \( kW_{\text{base}} \)\(^{753}\) = connected load kW for typical reach-in refrigerator or freezer door and frame with a heater.
  - = If actual \( kW_{\text{base}} \) is unknown, assume 0.195 kW for freezers and 0.092 kW for coolers.
- \( \text{NUMdoors} \) = number of reach-in refrigerator or freezer doors controlled by sensor
  - = Actual installed
- \( \text{ESF} \)\(^{754}\) = Energy Savings Factor; represents the percentage of hours annually that the door heater is powered off due to the controls.
  - = Assume 55% for humidity-based controls, 70% for conductivity-based controls
- \( \text{BF} \)\(^{755}\) = Bonus Factor; represents the increased savings due to reduction in cooling load inside the cases, and the increase in cooling load in the building space to cool the additional heat generated by the door heaters.

<table>
<thead>
<tr>
<th>Definition</th>
<th>Representative Evaporator Temperature Range, °F(^{756})</th>
<th>Typical Uses</th>
<th>BF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>-35 to 0</td>
<td>Freezers for times such as frozen pizza, ice cream, etc.</td>
<td>1.36</td>
</tr>
<tr>
<td>Medium</td>
<td>0 – 20</td>
<td>Coolers for items such as meat, milk, dairy, etc</td>
<td>1.22</td>
</tr>
<tr>
<td>High</td>
<td>20 – 45</td>
<td>Coolers for items such as floral, produce and meat preparation rooms</td>
<td>1.15</td>
</tr>
</tbody>
</table>

\( 8766 \) = annual hours of operation

**Summer Coincident Peak Demand Savings**

N/A

**Natural Gas Energy Savings**

N/A

---

\(^{753}\) A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different sources for this factor. Connecticut requires site-specific information, whereas New York’s characterization does not explicitly identify the \( kW_{\text{base}} \). Connecticut and Vermont provide values that are very consistent, and the simple average of these two values has been used for the purposes of this characterization.

\(^{754}\) A review of TRM methodologies from Vermont, New York, Wisconsin, and Connecticut reveals several different estimates of \( \text{ESF} \). Vermont is the only TRM that provides savings estimates dependent on the control type. Additionally, these estimates are the most conservative of all TRMs reviewed. These values have been adopted for the purposes of this characterization.


WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-RFG-DHCT-V01-120601

REVIEW DEADLINE: 1/1/2019
4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers

DESCRIPTION
This measure is applicable to the replacement of an existing, uncontrolled, and continuously operating standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins.

This measure achieves savings by installing a more efficient motor, the result of which produces less waste heat that the cooling system must reject.

If applicable, savings from this measure may be claimed in combination with measure 4.6.6 Evaporator Fan Control for Electrically Commutated Motors.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
This measure applies to the replacement of an existing standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins. The replacement unit must be an electronically commutated motor (ECM) with a minimum efficiency of 66%. If controls are added as part of the motor upgrade to reduce annual run time, additional savings may potentially be claimed using measure 4.6.6 Evaporator Fan Control.

DEFINITION OF BASELINE EQUIPMENT
The baseline is the existing shaded-pole motor(s) with no fan control operating 8760 hours continuously in a refrigerated display case or fan coil unit of a walk-in cooling unit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 15 years.

DEEMED MEASURE COST
The measure cost is assumed to be $177 per motor for a walk in cooler and walk in freezer.

LOADSHAPE
Loadshape C53 - Flat

COINCIDENCE FACTOR
The peak kW coincidence factor is 100%.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \text{Savings per motor} \times \text{motors} \]

Where:

757 DEER

758 Difference in the fully installed cost ($468) for ECM motor and controller, listed in Work Paper PGE3PREF126, “ECM for Walk-In Evaporator with Fan Controller,” June 20, 2012, and the measure cost specified in 4.6.6 ($291)
Savings per motor = based on the motor rating of the ECM motor:

<table>
<thead>
<tr>
<th>Evaporator Fan Motor Rating (of ECM)</th>
<th>Annual kWh Savings/motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>16W</td>
<td>408</td>
</tr>
<tr>
<td>1/15 - 1/20HP</td>
<td>1,064</td>
</tr>
<tr>
<td>1/5HP</td>
<td>1,409</td>
</tr>
<tr>
<td>1/3HP</td>
<td>1,994</td>
</tr>
<tr>
<td>1/2HP</td>
<td>2,558</td>
</tr>
<tr>
<td>3/4HP</td>
<td>2,782</td>
</tr>
</tbody>
</table>

motors = number of fan motors replaced

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta k\text{W} = \Delta \text{kWh} / \text{Hours} \times \text{CF} \times \text{motors}
\]

Where:

- \(\Delta \text{kWh}\) = Gross customer annual kWh savings for the measure, as listed above
- \(\text{Hours}\) = Full Load hours per year
  - = 8760
- \(\text{CF}\) = Summer Peak Coincident Factor
  - = 1.0

Other variables as defined above.

The following table provides the resulting kW savings (per motor):

<table>
<thead>
<tr>
<th>Evaporator Fan Motor Rating (of ECM)</th>
<th>Peak kW Savings/motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>16W</td>
<td>0.047</td>
</tr>
<tr>
<td>1/15 - 1/20HP</td>
<td>0.121</td>
</tr>
<tr>
<td>1/5HP</td>
<td>0.161</td>
</tr>
<tr>
<td>1/3HP</td>
<td>0.228</td>
</tr>
<tr>
<td>1/2HP</td>
<td>0.292</td>
</tr>
<tr>
<td>3/4HP</td>
<td>0.318</td>
</tr>
</tbody>
</table>

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A
4.6.5 ENERGY STAR Refrigerated Beverage Vending Machine

**DESCRIPTION**

ENERGY STAR qualified new and rebuilt vending machines incorporate more efficient compressors, fan motors, and lighting systems as well as low power mode option that allows the machine to be placed in low-energy lighting and/or low-energy refrigeration states during times of inactivity.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The refrigerated vending machine can be new or rebuilt but must meet the ENERGY STAR specifications which include low power mode.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline vending machine is a standard unit.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The deemed lifetime of this measure is 14 years.

**DEEMED MEASURE COST**

The incremental cost of this measure is $500.

**LOADSHAPE**

Loadshape C22 - Commercial Refrigeration

**COINCIDENCE FACTOR**

It is assumed that controls are only effective during off-peak hours and so have no peak-kW savings.

<table>
<thead>
<tr>
<th>Vending Machine Capacity (cans)</th>
<th>kWh Savings Per Machine w/o software</th>
<th>kWh Savings Per Machine w/ software</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;500</td>
<td>1,099</td>
<td>1,659</td>
</tr>
</tbody>
</table>

**Algorithm**

**CALCULATION OF SAVINGS**

Beverage machine savings are taken from the ENERGY STAR savings calculator and summarized in the following table. ENERGY STAR provides savings numbers for machines with and without control software. The average savings are calculated here.

**ELECTRIC ENERGY SAVINGS**

ENERGY STAR Vending Machine Savings

759 ENERGY STAR

760 ENERGY STAR

761 Savings from Vending Machine Calculator:

http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=VMC
### Table: Vending Machine Capacity (cans) vs. kWh Savings Per Machine

<table>
<thead>
<tr>
<th>Vending Machine Capacity (cans)</th>
<th>kWh Savings Per Machine w/o software</th>
<th>kWh Savings Per Machine w/ software</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 - 599</td>
<td>1,754</td>
<td>2,231</td>
</tr>
<tr>
<td>600 - 699</td>
<td>1,242</td>
<td>1,751</td>
</tr>
<tr>
<td>700 - 799</td>
<td>1,741</td>
<td>2,283</td>
</tr>
<tr>
<td>800+</td>
<td>713</td>
<td>1,288</td>
</tr>
<tr>
<td>Average</td>
<td>1,310</td>
<td>1,842</td>
</tr>
</tbody>
</table>

#### Summer Coincident Peak Demand Savings
N/A

#### Natural Gas Energy Savings
N/A

#### Water Impact Descriptions and Calculation
N/A

#### Deemed O&M Cost Adjustment Calculation
N/A

#### Measure Code: CI-RFG-ESVE-V02-150601

#### Review Deadline: 1/1/2019
4.6.6 Evaporator Fan Control for Electrically Commutated Motors

DESCRIPTION
This measure is for the installation of controls for Electronically Commutated Motors in existing medium temperature walk-in coolers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow. This measure achieves savings by controlling the motor(s) to run at lower speeds (or shut off entirely) when there is no refrigerant flow, the result of which produces less waste heat that the cooling system must reject.

If eligible, this measure may be claimed in combination with 4.6.4 Electronically Commutated Motors (ECM) for Walk-in and Reach-in Coolers / Freezers.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
The measure must control a minimum of 1/20 HP where fans operate continuously at full speed. The measure also must reduce fan motor power by at least 75% during the off cycle. This measure is not applicable if any of the following conditions apply:

- The compressor runs more than 4380 hours annually
- The evaporator fan does not run at full speed all the time
- The evaporator fan motor runs on poly-phase power
- Evaporator does not use off-cycle or time-off defrost.

DEFINITION OF BASELINE EQUIPMENT
In order for this characterization to apply, the existing condition must be a reach-in or walk-in freezer or cooler with continuously running evaporator fans driven by Electrically Commutated Motors.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 16 years.\textsuperscript{762}

DEEMED MEASURE COST
The measure cost is assumed to be $291.\textsuperscript{763}

LOADSHAPE

Loadshape C46 - Evaporator Fan Control

COINCIDENCE FACTOR
The measure has deemed kW savings therefore a coincidence factor does not apply.

\textsuperscript{762} Source: DEER
\textsuperscript{763} Source: DEER
Algorithm

CALCULATION OF SAVINGS

Savings are based on a measure created by Energy & Resource Solutions for the California Municipal Utilities Association\textsuperscript{764} and supported by a PGE workpaper. Note that climate differences across all California climate zones result in negligible savings differences, which indicates that the average savings for the California study should apply equally as well to Illinois. Savings found in the aforementioned source are presented in combination with savings from an ECM upgrade, however for the purposes of this measure only those associated with the controller are considered.

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \text{Savings per motor} \times \text{motors} \]

Where:

- **Savings per motor** = based on the motor rating of the ECM motor:
  
<table>
<thead>
<tr>
<th>Evaporator Fan Motor Rating (of ECM)</th>
<th>Annual kWh Savings/motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>16W</td>
<td>212</td>
</tr>
<tr>
<td>1/15 - 1/20HP</td>
<td>315</td>
</tr>
<tr>
<td>1/5HP</td>
<td>920</td>
</tr>
<tr>
<td>1/3HP</td>
<td>1,524</td>
</tr>
<tr>
<td>1/2HP</td>
<td>2,283</td>
</tr>
<tr>
<td>3/4HP</td>
<td>3,444</td>
</tr>
</tbody>
</table>

- **motors** = number of fan motors controlled

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[ \Delta \text{kW} = \text{Peak kW savings per motor} (\text{as listed in the table below}) \times \text{motors} (\text{as defined above}) \]

<table>
<thead>
<tr>
<th>Evaporator Fan Motor Rating (of ECM)</th>
<th>Peak kW Savings/motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>16W</td>
<td>0.024</td>
</tr>
<tr>
<td>1/15 - 1/20HP</td>
<td>0.036</td>
</tr>
<tr>
<td>1/5HP</td>
<td>0.105</td>
</tr>
<tr>
<td>1/3HP</td>
<td>0.174</td>
</tr>
<tr>
<td>1/2HP</td>
<td>0.261</td>
</tr>
<tr>
<td>3/4HP</td>
<td>0.393</td>
</tr>
</tbody>
</table>

NATURAL GAS ENERGY SAVINGS

N/A

\textsuperscript{764} See ‘EC_motor_with_controller_182014.xlsx’.
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: CI-RFG-EVPF-V03-180101

REVIEW DEADLINE: 1/1/2024
4.6.7 Strip Curtain for Walk-in Coolers and Freezers

DESCRIPTION
This commercial measure pertains to the installation of infiltration barriers (strip curtains) on walk-in coolers or freezers. Strip curtains impede heat transfer from adjacent warm and humid spaces into walk-ins when the main door is opened, thereby reducing the cooling load. As a result, compressor run time and energy consumption are reduced. The engineering assumption is that the walk-in door is open for varying durations per day based on facility type, and the strip curtain covers the entire door frame. All assumptions are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the CA Public Utility Commission.765

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
The efficient equipment is a strip curtain at least 0.06 inches thick766 added to a walk-in cooler or freezer. The new strip curtain must cover the entire area of the doorway when the door is opened.

DEFINITION OF BASELINE EQUIPMENT
The baseline assumption is a walk-in cooler or freezer that previously had either no strip curtain installed or an old, ineffective strip curtain installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 4 years767.

DEEMED MEASURE COST
The incremental capital cost for this measure is $10.22/sq ft of door opening 768

LOADSHAPE
Loadshape C22 - Commercial Refrigeration

COINCIDENCE FACTOR
The summer peak coincidence factor for this measure is 100%769.

---

765 The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission’s evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from shortterm monitoring of over 100 walk-in units. http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf.
766 Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.
767 DEER 2014 Effective Useful Life.
769 The summer coincident peak demand reduction is assumed as the total annual savings divided by the total number of hours per year, effectively assuming the average demand reduction is realized during the peak period. This is a reasonable assumption for refrigeration savings.
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh = \Delta kWh/\text{sq ft} \times A \]

Where:

\[ \Delta kWh/\text{sq ft} \] = Average annual kWh savings per square foot of infiltration barrier. Values can be found in Table 4.6.7 - 1.

\[ A \] = Doorway area. If the actual doorway area in square feet is unknown, then use the values found in Table 4.6.7 - 2.

Table 4.6.7 - 1: Default Energy Savings and for Strip Curtains

<table>
<thead>
<tr>
<th>Type</th>
<th>Pre-Existing Curtains</th>
<th>Energy Savings ΔkWh/sq ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supermarket - Cooler</td>
<td>Yes</td>
<td>37</td>
</tr>
<tr>
<td>Supermarket - Cooler</td>
<td>No</td>
<td>108</td>
</tr>
<tr>
<td>Supermarket - Freezer</td>
<td>Yes</td>
<td>119</td>
</tr>
<tr>
<td>Supermarket - Freezer</td>
<td>No</td>
<td>349</td>
</tr>
<tr>
<td>Convenience Store - Cooler</td>
<td>Yes</td>
<td>5</td>
</tr>
<tr>
<td>Convenience Store - Cooler</td>
<td>No</td>
<td>20</td>
</tr>
<tr>
<td>Convenience Store - Freezer</td>
<td>Yes</td>
<td>8</td>
</tr>
<tr>
<td>Convenience Store - Freezer</td>
<td>No</td>
<td>27</td>
</tr>
<tr>
<td>Restaurant - Cooler</td>
<td>Yes</td>
<td>8</td>
</tr>
<tr>
<td>Restaurant - Cooler</td>
<td>No</td>
<td>30</td>
</tr>
<tr>
<td>Restaurant - Freezer</td>
<td>Yes</td>
<td>34</td>
</tr>
<tr>
<td>Restaurant - Freezer</td>
<td>No</td>
<td>119</td>
</tr>
<tr>
<td>Refrigerated Warehouse</td>
<td>Yes</td>
<td>254</td>
</tr>
<tr>
<td>Refrigerated Warehouse</td>
<td>No</td>
<td>729</td>
</tr>
</tbody>
</table>

Table 4.6.7 - 2: Default Doorway Area by Facility Type

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Doorway Area (sq ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supermarket - Cooler</td>
<td>35</td>
</tr>
<tr>
<td>Supermarket - Freezer</td>
<td>35</td>
</tr>
<tr>
<td>Convenience Store - Cooler</td>
<td>21</td>
</tr>
<tr>
<td>Convenience Store - Freezer</td>
<td>21</td>
</tr>
<tr>
<td>Restaurant - Cooler</td>
<td>21</td>
</tr>
<tr>
<td>Restaurant - Freezer</td>
<td>21</td>
</tr>
<tr>
<td>Refrigerated Warehouse</td>
<td>80</td>
</tr>
</tbody>
</table>

770 The source algorithm from which the savings per square foot values are determined is based on Tamm’s equation (an application of Bernoulli’s equation) [Kalterveduste durch kuhlraumoffnungen. Tamm W., Kaltetechnik-Klimatisierung 1966;18;142-144;] and the ASHRAE handbook [American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2010. ASHRAE Handbook, Refrigeration: 13.4, 13.6].

771 Table 3-114 Default Energy Savings and Demand Reductions for Strip Curtains in Pennsylvania Public Utility Commission TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.

772 Assumed Doorway area for four different facility types including supermarket, convenience store, restaurant and refrigerated warehouse. Pennsylvania Public Utility Commission 2016 TRM, chapter 3.5.9 Strip Curtains for Walk-in Freezers and Coolers.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh \div 8766 \times CF \]

Where:

- 8766 = hours per year
- CF = Summer Peak Coincidence Factor for the measure
  = 1.0

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** CI-RFG-CRTN-V04-180101

**REVIEW DEADLINE:** 1/1/2022
4.6.8 Refrigeration Economizers

DESCRIPTION
This measure applies to commercial walk in refrigeration systems and includes two components, outside air economizers and evaporator fan controllers. Economizers save energy by bringing in outside air when weather conditions allow, rather than operating the compressor. Walk-in refrigeration systems evaporator fans run almost all the time; 24 hrs/day, 365 days/yr. This is because they must run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. However, evaporator fans are a very inefficient method of providing air circulation. Installing an evaporator fan control system will turn off evaporator fans while the compressor is not running, and instead turn on an energy-efficient 35 watt fan to provide air circulation, resulting in significant energy savings. This measure allows for economizer systems with evaporator fan controls plus a circulation fan and without a circulation fan.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure an economizer is installed on a walk in refrigeration system.

DEFINITION OF BASELINE EQUIPMENT
The baseline condition is a walk in refrigeration system without an economizer.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The estimated life of this measure is 15 years.\(^{773}\)

DEEMED MEASURE COST
The installation cost for an economizer is $2,558.\(^{774}\)

LOADSHAPE
Loadshape C22 - Commercial Refrigeration

COINCIDENCE FACTOR
The summer peak coincidence factor for this measure is assumed to be 0%\(^{775}\).

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS
Electric energy savings is calculated based on whether evaporator fans run all

With Fan Control Installed
\[
\Delta \text{kWh} = [\text{HP} \times \text{kWhCond}] + [((\text{kWEvap} \times \text{nFans}) - \text{kWCirc}) \times \text{Hours} \times \text{DCComp} \times \text{BF}] - [\text{kWEcon} \times \text{DCEcon} \times \text{Hours}]
\]

\(^{773}\) Estimated life from Efficiency Vermont TRM
\(^{774}\) Based on average of costs from Freeaire, Natural Cool, and Cooltrol economizer systems.
\(^{775}\) Based on the assumption that humidity levels will most likely be relatively high during the peak period, reducing the likelihood of demand savings.
Without Fan Control Installed

\[ \Delta k\text{Wh} = [\text{HP} \times k\text{WCond}] - [k\text{WEcon} \times D\text{CEcon} \times \text{Hours}] \]

Where:

- **HP** = Horsepower of Compressor
  - = actual installed

- **kWCond** = Condensing unit savings, per hp. (value from savings table)  
<p>|</p>
<table>
<thead>
<tr>
<th>Hermetic / Semi-Hermetic</th>
<th>Scroll</th>
<th>Discus</th>
</tr>
</thead>
<tbody>
<tr>
<td>kWh/HP</td>
<td>1,256</td>
<td>1,108</td>
</tr>
</tbody>
</table>

- **Hours** = Number of annual hours that economizer operates  
<p>|</p>
<table>
<thead>
<tr>
<th>Region (city)</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>2,376</td>
</tr>
<tr>
<td>2 (Chicago/O’Hare)</td>
<td>1,968</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,728</td>
</tr>
<tr>
<td>4 (Belleview)</td>
<td>1,488</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,224</td>
</tr>
</tbody>
</table>

- **DCComp** = Duty cycle of the compressor
  - = 50%  

- **kWEvap** = Connected load kW of each evaporator fan,
  - = If known, actual installed. Otherwise assume 0.123 kW  

- **kWCirc** = Connected load kW of the circulating fan
  - = If known, actual installed. Otherwise assume 0.035 kW

- **nFans** = Number of evaporator fans
  - = actual number of evaporator fans

- **DCEcon** = Duty cycle of the economizer fan on days that are cool enough for the economizer to be working
  - = If known, actual installed. Otherwise assume 63%  

---

776 Savings table uses Economizer Calc.xls. Assume 5HP compressor size used to develop kWh/Hp value. No floating head pressure controls and compressor is located outdoors

777 In the source TRM (VT) this value was 2,996 hrs based on 38° F cooler setpoint, Burlington VT weather data, and 5 degree economizer deadband. The IL numbers were calculated by using weather bin data for each location (number of hours < 38F at each location is the Hours value).

778 A 50% duty cycle is assumed based on examination of duty cycle assumptions from Richard Travers (35%-65%), Cooltrol (35%-65%), Natural Cool (70%), Pacific Gas & Electric (58%). Also, manufacturers typically size equipment with a built-in 67% duty factor and contractors typically add another 25% safety factor, which results in a 50% overall duty factor. (as referenced by the Efficiency Vermont, Technical Reference User Manual)

779 Based on an a weighted average of 80% shaded pole motors at 132 watts and 20% PSC motors at 88 watts

780 Wattage of fan used by Freeaire and Cooltrol. This fan is used to circulate air in the cooler when the evaporator fan is turned off. As such, it is not used when fan control is not present

781 Average of two manufacturer estimates of 50% and 75%.
BF = Bonus factor for reduced cooling load from running the evaporator fan less or (1.3)\(^782\)

\[\text{kWEcon} = \text{Connected load kW of the economizer fan}\]

= If known, actual installed. Otherwise assume 0.227 kW.\(^783\)

**EXAMPLE**

For example, adding an outdoor air economizer and fan controls in Rockford to a 5 hp walk in refrigeration unit with 3 evaporator fans would save:

\[
\Delta\text{kWh} = ([\text{HP} \times \text{kWhCond}] + [[[\text{kWEvap} \times \text{nFans}] - \text{kWCirc}] \times \text{Hours} \times \text{DCComp} \times \text{BF}] - [\text{kWEcon} \times \text{DCEcon} \times \text{Hours}])
\
= [5 \times 1256] + [[[0.123 \times 3] - 0.035] \times 2376 \times 0.5 \times 1.3] - [0.227 \times 0.63 \times 2376]
\
= 6456 \text{kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[\Delta\text{kW} = \Delta\text{kWh} / \text{Hours}\]

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-RFG-ECON-V05-150601**

**REVIEW DEADLINE: 1/1/2020**

---

\(^{782}\) Bonus factor \((1 + 1/3.5)\) assumes COP of 3.5, based on the average of standard reciprocating and discus compressor efficiencies with a Saturated Suction Temperature of 20°F and a condensing temperature of 90°F.

\(^{783}\) The 227 watts for an economizer is calculated from the average of three manufacturers: Freeaire (186 Watts), Cooltrol (285 Watts), and Natural Cool (218 Watts).
4.6.9 Night Covers for Open Refrigerated Display Cases

**DESCRIPTION**

This measure is the installation of fitted covers on existing open-type refrigerated and freezer display cases that are deployed during the facility unoccupied hours. Night covers are designed to reduce refrigeration energy consumption by reducing the work done by the compressor. Night covers reduce the heat and moisture entry into the refrigerated space through various heat transfer mechanisms. By fully or partially covering the case opening, night covers reduce the convective heat transfer into the case through reduced air infiltration. Additionally, they provide a measure of insulation, reducing conduction into the case, and also decrease radiation into the case by blocking radiated heat from entering the refrigerated space.

**DEFINITION OF EFFICIENT EQUIPMENT**

Curtains or covers on top of open refrigerated or freezer display cases that are applied at least six hours (during off-hours) in a 24-hour period.

**DEFINITION OF BASELINE EQUIPMENT**

Refrigerated and freezer, open-type display case in vertical, semi-vertical, and horizontal displays, with no night cover.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is 5 years, based on DEER 2014.\(^{784}\)

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $42 per linear foot of cover installed including material and labor.\(^{785}\)

**LOADSHAPE**

Loadshape 22: Commercial Refrigeration

**COINCIDENCE FACTOR**

N/A – savings occur at night only.

---

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[\Delta \text{kWh} = ES \times L\]

Where:

- ES = the energy savings (\(\Delta \text{kWh/ft}\)) found in table below:

---


### Display Case Description

<table>
<thead>
<tr>
<th>Display Case Description</th>
<th>Case Temperature Range (°F)</th>
<th>Annual Electricity Use kWh/ft</th>
<th>ES ΔkWh/ft reduction (= 9% reduction of electricity use)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Open, Remote Condensing, Medium Temperature</td>
<td>35°F to 55°F</td>
<td>1453</td>
<td>131</td>
</tr>
<tr>
<td>Vertical Open, Remote Condensing, Low Temperature</td>
<td>0°F to 30°F</td>
<td>3292</td>
<td>296</td>
</tr>
<tr>
<td>Vertical Open, Self-Contained Medium Temperature</td>
<td>35°F to 55°F</td>
<td>2800</td>
<td>252</td>
</tr>
<tr>
<td>Horizontal Open, Remote Condensing, Medium Temperature</td>
<td>35°F to 55°F</td>
<td>439</td>
<td>40</td>
</tr>
<tr>
<td>Horizontal Open, Remote Condensing, Low Temperature</td>
<td>0°F to 30°F</td>
<td>1007</td>
<td>91</td>
</tr>
<tr>
<td>Horizontal Open, Self-Contained, Medium Temperature</td>
<td>35°F to 55°F</td>
<td>1350</td>
<td>121</td>
</tr>
<tr>
<td>Horizontal Open, Self-Contained, Low Temperature</td>
<td>0°F to 30°F</td>
<td>2749</td>
<td>247</td>
</tr>
</tbody>
</table>

\[ L = \text{the length of the refrigerated case in linear feet} \]
\[ = \text{Actual} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Peak savings are null because savings occur at night only.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

---

786 Energy Conservation Standards for Commercial Refrigeration Equipment: Technical Support Document, U.S. Department of Energy, September 2013. The information required to estimate annual energy savings for refrigerated display cases is taken from the 2013-2014 U.S. Department of Energy (DOE) energy conservation standard rulemaking for Commercial Refrigerated Equipment. During the rulemaking process, DOE estimates the energy savings specific to night covers through extensive simulation and energy models that are validated by both manufacturers of night covers and refrigerated cases. The information is also referenced from a study done by Southern California Edison and testing by Technischer Überwachungs-Verein Rheinland, which are used by DOE for the rulemaking process.


788 Technischer Überwächungs-Verein Rheinland E.V. Laboratory test results for energy savings on refrigerated dairy case, conducted for Econofrost.
MEASURE CODE: CI-RFG-NCOV-V01-150601

REVIEW DEADLINE: 1/1/2024
4.6.10 High Speed Rollup Doors

**DESCRIPTION**

This measure entails the installation of High Speed Doors in refrigerated warehouses. High speed doors can save energy by lowering infiltration through a reduction in time that cooled spaces are exposed to ambient outdoor conditions. This in turn can lower the demand on refrigeration systems.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a High Speed Door installed on the loading dock doorway of a refrigerated space. The high speed door is assumed to act as a primary door. It should be noted that for high-traffic applications (about 45 door passages per hour, using the defaults for this measure) a custom analysis is necessary to ensure that high-speed rollup doors will provide savings, because strip curtains may outperform the high speed door, if no other open-door protection device is installed.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is existing strip curtains on doorways to a loading dock. During times of traffic, primary doors are left open, leaving just the strip curtains as open-doorway protection.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 12 years.\(^{789}\)

**DEEMED MEASURE COST**

The incremental measure cost is $150/sq.ft.\(^{790}\)

**LOADSHAPE**

Loadshape C22 - Commercial Refrigeration

**COINCIDENCE FACTOR**

The coincidence factor is assumed to be 1.00.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Electric savings consider the change in loading on the refrigeration system as well as the consumption of the drive on the high speed door. The following algorithms are based heavily on those derived and described in chapter 24 Refrigerated-Facility Loads of the ASHRAE Refrigeration Handbook.

\[
\Delta kW h = \left(0.00008333 \times q \times D_f \times \eta \times [D_{EB}(1 - E_B) - D_{IE}(1 - E_E)] - D_{LM}M\right) \times t
\]

Where:

\(^{789}\) DEER 2008, Consulted from similar refrigerated warehouse measures.

\(^{790}\) Rite Hite – Industrial High Speed Doors
0.00008333 = conversion from Btu/h to tons

\[ q = \text{sensible and latent refrigeration load for fully established flow, Btu/h} \]

\[ q = 3790 \times W \times H^{1.5} \times \left( \frac{Q_s}{A} \right) \times \left( \frac{1}{R_s} \right) \]

\( W \) = width of doorway, in feet. Custom input.

\( H \) = height of doorway, in feet. Custom input.

\( Q_s \) = Sensible heat load of infiltration air per square foot of door way opening, as read from the following figure and dependent on infiltration air temperature and cooled space temperature. If unknown, infiltration temperature can be assumed to be 50°F, cooler temperature 35°F and freezer temperature -10°F, resulting in values of 0.06 for a cooler and 0.5 for a freezer.

\( A \) = Sensible heat load of infiltration air per square foot of doorway opening, as read from the following figure and dependent on infiltration air temperature and cooled space temperature. If unknown, infiltration temperature can be assumed to be 50°F, cooler temperature 35°F and freezer temperature -10°F, resulting in values of 0.06 for a cooler and 0.5 for a freezer.

\( R_s \) = Sensible heat ratio of the infiltration air heat gain, as read or interpolated from the chart below or from a psychometric chart, dependent on temperature and relative humidity of infiltration air and cooled space temperature. If unknown, use the same assumptions as previously with a warm space relative humidity value of 70%, resulting in values of 0.685 (interpolated) for coolers and 0.73 (interpolated) for freezers.

---

791 Taken to represent the overall annual average temperature in Illinois. TMY3 data for the five weather regions defined by the TRM indicate averages that fall within the range of 47.6 (Rockford) to 55.9 (Marion).

792 Refrigerated Warehouse, 2013 California Building Energy Standards, CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE), March 2011

793 Taken to represent the overall annual average in Illinois. TMY3 data for the five weather regions defined by the TRM indicate averages that fall within the range of 69.1 (Springfield) to 72.1 (Rockford).
### High Speed Rollup Doors

#### Warm Space

<table>
<thead>
<tr>
<th>Temp. (°F)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>0.60</td>
<td>0.58</td>
<td>0.56</td>
<td>0.53</td>
<td>0.50</td>
<td>0.47</td>
</tr>
<tr>
<td>80</td>
<td>0.66</td>
<td>0.64</td>
<td>0.61</td>
<td>0.59</td>
<td>0.56</td>
<td>0.53</td>
</tr>
<tr>
<td>90</td>
<td>0.72</td>
<td>0.70</td>
<td>0.68</td>
<td>0.66</td>
<td>0.63</td>
<td>0.61</td>
</tr>
<tr>
<td>40</td>
<td>0.79</td>
<td>0.78</td>
<td>0.76</td>
<td>0.75</td>
<td>0.73</td>
<td>0.72</td>
</tr>
<tr>
<td>50</td>
<td>0.86</td>
<td>0.84</td>
<td>0.82</td>
<td>0.80</td>
<td>0.78</td>
<td>0.76</td>
</tr>
</tbody>
</table>

#### Cold Space at 50% rh

<table>
<thead>
<tr>
<th>Temp. (°F)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>0.70</td>
<td>0.67</td>
<td>0.64</td>
<td>0.62</td>
<td>0.59</td>
<td>0.56</td>
</tr>
<tr>
<td>80</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
<td>0.71</td>
<td>0.69</td>
<td>0.67</td>
</tr>
<tr>
<td>90</td>
<td>0.83</td>
<td>0.81</td>
<td>0.79</td>
<td>0.77</td>
<td>0.75</td>
<td>0.73</td>
</tr>
<tr>
<td>40</td>
<td>0.90</td>
<td>0.88</td>
<td>0.86</td>
<td>0.84</td>
<td>0.82</td>
<td>0.80</td>
</tr>
<tr>
<td>50</td>
<td>0.96</td>
<td>0.94</td>
<td>0.92</td>
<td>0.90</td>
<td>0.88</td>
<td>0.86</td>
</tr>
</tbody>
</table>

### Formula

\[ D_t = \frac{P \theta_{PB} + 60 \theta_{OB}}{3600 \theta_d} \]

- **\( D_t \)** = doorway flow factor. Equal to 0.8 for a doorway between a freezer and a dock and 1.1 for a doorway between a cooler and a dock.\(^{794}\)

- **\( \eta \)** = Efficiency of refrigeration system (kW/ton). Custom input, if unknown assume 1.6 kW/ton for coolers and 2.4 kW/ton for freezers.\(^{795}\)

- **\( D_{tB} \)** = decimal portion of time doorway is open in the baseline condition. If during facility operating hours, the primary doors are left open, leaving only open-doorway protective devices (e.g., strip curtains) as a barrier, this is considered 1.0. If primary doors are actively operated and do not remain open for the entire time the facility is in operation, refer to the following calculation.

\[ D_{tB} = \frac{(P \theta_{PB} + 60 \theta_{OB})}{3600 \theta_d} \]

- **\( P \)** = Number of passages through doorway per hour.
- **\( \theta_{PB} \)** = Door open to close time in seconds.
- **\( \theta_{OB} \)** = Time door remains open in minutes.
- **\( \theta_d \)** = Period of time considered in hours, 1 hr.

- **\( D_{tE} \)** = decimal portion of time doorway is open in the efficient condition.

---


\(^{795}\) Professional judgement, in alignment with typical freezer and cooler performance found in the Michigan Energy Measures Database (MEMD).
\[ D_{TE} = \frac{(P \theta_p + 60 \theta_o)}{3600 \theta_d} \]

- \( P \) = Number of passages through doorway per hour. Custom input, assume 5.9 if unknown.
- \( \theta_p \) = Door open to close time in seconds. Custom input, assume 7.5 seconds if unknown.
- \( \theta_o \) = Time door remains open in minutes. Custom input, assume 3 minutes if unknown.
- \( \theta_d \) = Period of time considered in hours, 1 hr.

\[ D_{TM} = \frac{P \theta_p}{3600 \theta_d} \]

Variables defined above.

- \( E_B \) = effectiveness of baseline open-doorway protective device (strip curtains). Equal to 0.85.
- \( E_E \) = effectiveness of efficient open-doorway protective device. Equal to 0, unless an additional protective device exists to limit infiltration during times when the high-speed door is open.
- \( M \) = operating input power of the high speed door motor, in kW.
  - Custom input, assume 1.49kW if unknown.
- \( t \) = hours per year when primary doors to the cooled space are open.
  - Custom input, assume 2,959 hrs/yr if unknown.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = (\Delta kWh / t) \times CF \]

Where

- \( CF \) = Summer peak coincidence factor for this measure
  - 1.0

All other variables as defined above.

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

---

798 Professional judgement
800 Rite Hite – Industrial High Speed Doors, product line commonly uses 2HP drives.
801 Based on a ComEd survey that obtained the number of hours per week certain building types operate. Warehouses had an average response of 55.6 and industrials had 58.2. Calculated by taking the simple average of the two and multiplying by 52 weeks/yr.
DEEMED O&M COST ADJUSTMENT CALCULATION

Manufacturers suggest annual inspection and maintenance (such as patching tears) of high speed doors. At a minimum, greasing of fittings and oil top-off should be carried out annually. This is estimated at a cost of $150 per year\textsuperscript{802}.

MEASURE CODE: CI-RFG-HSRD-V01-180101

REVIEW DEADLINE: 1/1/2022

\textsuperscript{802} Assumes approximately 1 hour of maintenance, based on manufacturer product spec sheets.
4.7 Compressed Air

4.7.1 VSD Air Compressor

DESCRIPTION
This measure relates to the installation of an air compressor with a variable frequency drive, load/no load controls or variable displacement control. The baseline compressors defined choke off the inlet air to modulate the compressor output, which is not efficient. Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility’s load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is a modulating compressor with blow down ≤ 40 hp

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
10 years.

DEEMED MEASURE COST

\[ \text{IncrementalCost (\$)} = (127 \times \text{hp}_{\text{compressor}}) + 1446 \]

Where:

127 and 1446\textsuperscript{803} = compressor motor nominal hp to incremental cost conversion factor and offset

\[ \text{hp}_{\text{compressor}} \] = compressor motor nominal

DEEMED O&M COST ADJUSTMENTS
N/A

LOADSHAPE
Loadshape C35 - Industrial Process

COINCIDENCE FACTOR
The coincidence factor equals 0.95

\textsuperscript{803} Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost. Several Vermont vendors were surveyed to determine the cost of equipment. See “Compressed Air Analysis.xls” and “Compiled Data ReQuest Results.xls” for incremental cost details.
Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = 0.9 \times h_{\text{p, compressor}} \times \text{HOURS} \times (C_{\text{b}} - C_{\text{e}}) \]

Where:

- \( \Delta \text{kWh} \) = gross customer annual kWh savings for the measure
- \( h_{\text{p, compressor}} \) = compressor motor nominal hp
- \( 0.9^{804} \) = compressor motor nominal hp to full load kW conversion factor
- \( \text{HOURS} \) = compressor total hours of operation below depending on shift

<table>
<thead>
<tr>
<th>Shift (Hours)</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single shift  (8/5)</td>
<td>1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)</td>
</tr>
<tr>
<td>2-shift (16/5)</td>
<td>3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)</td>
</tr>
<tr>
<td>3-shift (24/5)</td>
<td>5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)</td>
</tr>
<tr>
<td>4-shift (24/7)</td>
<td>8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)</td>
</tr>
</tbody>
</table>

- \( C_{\text{b}} \) = baseline compressor factor\textsuperscript{805}
  - = 0.890
- \( C_{\text{e}} \) = efficient compressor \textsuperscript{806}
  - = 0.705

**EXAMPLE**

For example a VFD compressor with 10 HP operating in a 1 shift facility would save

\[ \Delta \text{kWh} = 0.9 \times 10 \times 1976 \times (0.890 – 0.705) = 3290 \text{ kWh} \]

\textsuperscript{804} Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities on Long Island. See “BHP Weighted Compressed Air Load Profiles v2.xls”.

\textsuperscript{805} 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. “See “BHP Weighted Compressed Air Load Profiles.xls” for source data and calculations (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).

\textsuperscript{806} Ibid.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh / \text{HOURS} \times CF \]

**EXAMPLE**
For example a VFD compressor with 10 HP operating in a 1 shift facility would save

\[ \Delta kW = \frac{3290}{1976} \times 0.95 \]

\[ \Delta kW = 1.58 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-VSDA-V01-120601**

**REVIEW DEADLINE: 1/1/2019**
4.7.2 Compressed Air Low Pressure Drop Filters

**DESCRIPTION**

Low pressure drop filters remove solids and aerosols from compressed air systems with a longer life and lower pressure drop than standard coalescing filters, resulting in better efficiencies.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient condition is a low pressure drop filter with pressure drop not exceeding 1 psid when new and 3 psid at element change.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standard coalescing filter with a pressure drop of 3 psid when new and 5 or more at element change.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

5 years

**DEEMED MEASURE COST**

The incremental cost for this measure is estimated to be $1000 Incremental cost per filter

**LOADSHAPE**

Loadshape C35 - Industrial Process

**COINCIDENCE FACTOR**

The coincidence factor equals 0.95

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = (\text{kW}_{\text{typical}} \times \Delta \text{P} \times \text{SF} \times \text{Hours} / \text{HP}_{\text{typical}}) \times \text{HP}_{\text{real}} \]

Where:

- \( \text{kW}_{\text{typical}} \) = Adjusted compressor power (kW) based on typical compressor loading and operating profile. Use Use actual compressor control type if known:

---

[^807]: Incremental cost research found in LPDF Costs. xlsx
### Compressor kW typical

<table>
<thead>
<tr>
<th>Control Type</th>
<th>kW_{typical}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocating - On/off Control</td>
<td>70.2</td>
</tr>
<tr>
<td>Reciprocating - Load/Unload</td>
<td>74.8</td>
</tr>
<tr>
<td>Screw - Load/Unload</td>
<td>82.3</td>
</tr>
<tr>
<td>Screw - Inlet Modulation</td>
<td>82.5</td>
</tr>
<tr>
<td>Screw - Inlet Modulation w/ Unloading</td>
<td>82.5</td>
</tr>
<tr>
<td>Screw - Variable Displacement</td>
<td>73.2</td>
</tr>
<tr>
<td>Screw - VFD</td>
<td>70.8</td>
</tr>
</tbody>
</table>

= If the actual compressor control type is not known, then use a weighted average based on the following market assumptions:

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Share %</th>
<th>kW_{typical}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market share estimation for load/unload control compressors</td>
<td>40%</td>
<td>74.8</td>
</tr>
<tr>
<td>Market share estimation for modulation w/unloading control compressors</td>
<td>40%</td>
<td>82.5</td>
</tr>
<tr>
<td>Market share estimation for variable displacement control compressors</td>
<td>20%</td>
<td>73.2</td>
</tr>
</tbody>
</table>

| Weighted Average                                                            | 77.6    |

\[ \Delta P = \text{Reduced filter loss (psi)} \]

\[ = 2 \text{ psi}^{810} \]

\[ SF = 1\% \text{ reduction in power per 2 psi reduction in system pressure is equal to 0.5\% reduction per 1 psi, or a Savings Factor of 0.005}^{811} \]

<table>
<thead>
<tr>
<th>Hours</th>
<th>= depending on shifts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time) + 500 hrs maintenance = 2476 hrs</td>
<td></td>
</tr>
<tr>
<td>2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time) + 500 hrs maintenance = 4452 hrs</td>
<td></td>
</tr>
<tr>
<td>3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time) + 500 hrs maintenance = 6428 hrs</td>
<td></td>
</tr>
<tr>
<td>4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)</td>
<td></td>
</tr>
</tbody>
</table>

\[ HP_{typical} = \text{Nominal HP for typical compressor} = 100 \text{ hp}^{812} \]

---

808 See “Industrial System Standard Deemed Saving Analysis.xls”

809 See “Industrial System Standard Deemed Saving Analysis.xls”

810 Assumed pressure will be reduced from a roughly 3 psi pressure drop through a filter to less than 1 psi, for a 2 psi savings


812 Industrial System Standard Deemed Saving Analysis.xls
**HP_{real}** = Total HP of real compressors distributing air through filter. This should include the total horsepower of the compressors that normally run through the filter, but not backup compressors

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh / \text{HOURS} \times CF \]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-CALPDF-V01-140601**

**REVIEW DEADLINE: 1/1/2020**
4.7.3 Compressed Air No-Loss Condensate Drains

**DESCRIPTION**

No-loss condensate drains remove condensate as needed without venting compressed air, resulting in less air demand and consequently better efficiency. Replacement or upgrades of existing no-loss drains are not eligible for the incentive.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient condition is installation of no-loss condensate drains.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is installation of standard condensate drains (open valve, timer, or both)

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

10 years

**DEEMED MEASURE COST**

$700 per drain \(^8^1^3\)

**LOADSHAPE**

Loadshape C35 - Industrial Process

**COINCIDENCE FACTOR**

The coincidence factor equals 0.95

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = \text{CFM}_{\text{reduced}} \times \text{kW}_{\text{CFM}} \times \text{Hours} \]

Where:

- \( \text{CFM}_{\text{reduced}} \) = Reduced air consumption (CFM) per drain
- \( \text{CFM} = 3 \) \(^8^1^4\)
- \( \text{kW}_{\text{CFM}} \) = System power reduction per reduced air demand (kw/CFM) depending on the type of compressor control:

\(^8^1^3\) Based on empirical project data from ComEd Comprehensive Compressed Air Study program and VEIC review of pricing data found in CAS Cost Data.xls

\(^8^1^4\) Reduced CFM consumption is based on an a timer drain opening for 10 seconds every 300 seconds as the baseline. See “Industrial System Standard Deemed Saving Analysis.xls”
System Power Reduction per Reduced Air Demand\textsuperscript{815}

<table>
<thead>
<tr>
<th>Control Type</th>
<th>kW / CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocating - On/off Control</td>
<td>0.184</td>
</tr>
<tr>
<td>Reciprocating - Load/Unload</td>
<td>0.136</td>
</tr>
<tr>
<td>Screw - Load/Unload</td>
<td>0.152</td>
</tr>
<tr>
<td>Screw - Inlet Modulation</td>
<td>0.055</td>
</tr>
<tr>
<td>Screw - Inlet Modulation w/ Unloading</td>
<td>0.055</td>
</tr>
<tr>
<td>Screw - Variable Displacement</td>
<td>0.153</td>
</tr>
<tr>
<td>Screw - VFD</td>
<td>0.178</td>
</tr>
</tbody>
</table>

Or if compressor control type is unknown, then a weighted average based on market share can be used:

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Share %</th>
<th>kW / CFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market share estimation for load/unload control compressors</td>
<td>40%</td>
<td>0.136</td>
</tr>
<tr>
<td>Market share estimation for modulation w/unloading control compressors</td>
<td>40%</td>
<td>0.055</td>
</tr>
<tr>
<td>Market share estimation for variable displacement control compressors</td>
<td>20%</td>
<td>0.153</td>
</tr>
</tbody>
</table>

Weighted Average 0.107

Hours = Compressed air system pressurized hours

=6136 hours\textsuperscript{816}

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-CANCLD-V01-140601**

**REVIEW DEADLINE: 1/1/2020**

\textsuperscript{815} Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. See “Industrial System Standard Deemed Saving Analysis.xls”

\textsuperscript{816} US DOE, Evaluation of the Compressed Air Challenge® Training Program, Page 19
4.7.4 Efficient Compressed Air Nozzles

**DESCRIPTION**

This measure is for the replacement of standard air nozzle with high-efficiency air nozzle used in a compressed air system. High-efficiency air nozzles reduce the amount of air required to blow off parts or for drying. These nozzles utilize the Coandă effect to pull in free air to accomplish tasks with significantly less compressed air. High-efficiency nozzles often replace simple copper tubes. These nozzles have the added benefits of noise reduction and improved safety in systems with greater than 30 psig.

**DEFINITION OF EFFICIENT EQUIPMENT**

The high-efficiency air nozzle must meet the following specifications:

1. High-efficiency air nozzle must replace continuous open blow-offs
2. High-efficiency air nozzle must meet SCFM rating at 80 psig less than or equal to: 1/8” 11 SCFM, 1/4” 29 SCFM, 5/16” 56 SCFM, 1/2” 140 SCFM.
3. Manufacturer’s specification sheet of the high-efficiency air nozzle must be provided along with the make and model

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standard air nozzle

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is 15 years

**DEEMED MEASURE COST**

The estimated incremental measure costs are presented in the following table

<table>
<thead>
<tr>
<th>Nozzle Diameter</th>
<th>1/8”</th>
<th>1/4”</th>
<th>5/16”</th>
<th>1/2”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average IMC</td>
<td>$42</td>
<td>$57</td>
<td>$87</td>
<td>$121</td>
</tr>
</tbody>
</table>

**LOADSHAPE**

Loadshape C35 - Industrial Process

**COINCIDENCE FACTOR**

The coincidence factor equals 0.95

---


Algorithm

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta kWh = (SCFM \times SCFM\%\text{Reduced}) \times kW/CFM \times %\text{USE} \times \text{HOURS} \]

Where:

- **SCFM** = Air flow through standard nozzle. Use actual rated flow at 80 psi if known. If unknown, the table below includes the CFM by orifice diameter.  
  
<table>
<thead>
<tr>
<th>Orifice Diameter</th>
<th>SCFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8”</td>
<td>21</td>
</tr>
<tr>
<td>1/4”</td>
<td>58</td>
</tr>
<tr>
<td>5/16”</td>
<td>113</td>
</tr>
<tr>
<td>1/2”</td>
<td>280</td>
</tr>
</tbody>
</table>

- **SCFM\%\text{Reduced}** = Percent in reduction of air loss per nozzle. Estimated at 50%  

- **kW/CFM** = System power reduction per air demand (kW/CFM) depending on the type of air compressor found in table below  
  
<table>
<thead>
<tr>
<th>Air Compressor Type</th>
<th>( \Delta kW/CFM )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reciprocating – On/off Control</td>
<td>0.18</td>
</tr>
<tr>
<td>Reciprocating – Load/Unload</td>
<td>0.14</td>
</tr>
<tr>
<td>Screw – Load/Unload</td>
<td>0.15</td>
</tr>
<tr>
<td>Screw – Inlet Modulation</td>
<td>0.06</td>
</tr>
<tr>
<td>Screw – Inlet Modulation w/ Unloading</td>
<td>0.06</td>
</tr>
<tr>
<td>Screw – Variable Displacement</td>
<td>0.15</td>
</tr>
<tr>
<td>Screw - VFD</td>
<td>0.18</td>
</tr>
</tbody>
</table>

- **%\text{USE}** = percent of the compressor total operating hours that the nozzle is in use
- **Hours** = Compressed air system pressurized hours.
- **Hours** = Use actual hours if known, otherwise assume values in table below:

819 Review of manufacturer’s information  
821 Conservative estimate based on average values provided by the Compressed Air Challenge Training Program, Machinery’s Handbook 25th Edition, and manufacturers’ catalog.  
822 Calculated based on the type of compressor control. This assumes the compressor will be between 40% and 100% capacity before and after the changes to the system demand. See “Industrial System Standard Deemed Saving Analysis.xls”  
823 Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 5 seconds of blow-off per minute of compressor run time is used.
### Shift Hours

<table>
<thead>
<tr>
<th>Shift</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Shift</td>
<td>1976</td>
</tr>
<tr>
<td>Two Shifts</td>
<td>3952</td>
</tr>
<tr>
<td>Three Shifts</td>
<td>5928</td>
</tr>
<tr>
<td>Four Shifts or Continual Operation</td>
<td>8320</td>
</tr>
<tr>
<td>Unknown / Weighted average&lt;sup&gt;824&lt;/sup&gt;</td>
<td>5702</td>
</tr>
</tbody>
</table>

#### Summer Coincident Peak Demand Savings

\[
\Delta kW = \Delta kWh / \text{HOURS} \times CF
\]

Where:

- \( \Delta kWh = \) as calculated above
- \( CF = 0.95 \)

#### Natural Gas Savings

N/A

#### Water Impact Descriptions and Calculation

N/A

#### Deemed O&M Cost Adjustment Calculation

N/A

#### Measure Code CI-MSC-CNOZ-V01-150601

**Review Deadline:** 1/1/2022

---

<sup>824</sup> Weighting of 16% single shift, 23% two shift, 25% three shift and 36% continual based on DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules
4.7.5 Efficient Refrigerated Compressed Air Dryer

**DESCRIPTION**

An air dryer is an essential component in a compressed air system that prevents condensate from being deposited in the compressed air supply lines of a facility. If the warm, saturated compressed air is supplied directly into the plant, excess condensate will form in the compressed air supply lines. Uncontrolled condensate can damage demand-side tools and process equipment. Secondly, in an oil-flooded rotary screw compressor, the residual oil from compression can be carried along the supply lines potentially damaging process equipment. Industries that use compressed air for processes make use of various types of dryers including refrigerated dryers (both cycling and non-cycling). For this measure, three types of refrigerated air dryers will be considered: thermal mass, variable speed and digital scroll. All of these technologies offer better part load performance compared to non-cycling refrigerated dryers, thereby offering energy savings during periods when the dryer is not operating at peak capacity.

This measure was developed to be applicable to the following program types: TOS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

A new, high efficiency thermal mass dryer, variable speed dryer, or digital scroll dryer.

**DEFINITION OF BASELINE EQUIPMENT**

A standard non-cycling refrigerated compressed air dryer of comparable capacity.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

THE MEASURE LIFE IS 10 YEARS825.

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $6 per CFM.826

**LOADSHAPE**

Loadshape C35 – Industrial Process

**COINCIDENCE FACTOR**

The coincidence factor equals 0.95

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = P_s \times (\text{EC50}_{\text{baseline}} - \text{EC50}_{\text{efficient}}) \times \text{HOURS} \times \text{CFM} \]


826 Analysis of material cost between cycling and non-cycling dryers according to prices from Grainger. Cost provided is the average incremental cost when comparing non-cycling and cycling dryers of the same CFM capacity. [http://www.grainger.com/category/refrigerated-compressed-air-dryers/compressed-air-treatment/pneumatics/ecatalog/N-kk57bc=sy](http://www.grainger.com/category/refrigerated-compressed-air-dryers/compressed-air-treatment/pneumatics/ecatalog/N-kk57bc=sy)
Where:

\[ P_s = \text{Full flow specific power of the dryer} \]
\[ = 0.007 \text{ kW/CFM}^{827} \text{ (for both baseline and efficient equipment)} \]

\[ \text{EC50}_{\text{baseline}} = \text{Energy consumption ratio of baseline dryer at 50\%^{828} inlet load capacity as compared to fully loaded operating conditions.}^{829} \]
\[ = 0.843 \]

\[ \text{EC50}_{\text{efficient}} = \text{Energy consumption ratio of efficient dryer at 50\% inlet load capacity as compared to fully loaded operating conditions.} \]
\[ = \text{Dependent on efficient dryer type, refer to the following table}^{830}: \]

<table>
<thead>
<tr>
<th>Dryer Type</th>
<th>EC50efficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal-Mass</td>
<td>0.729</td>
</tr>
<tr>
<td>VSD</td>
<td>0.501</td>
</tr>
<tr>
<td>Digital Scroll</td>
<td>0.551</td>
</tr>
</tbody>
</table>

\[ \text{HOURS} = \text{Compressed air system pressurized hours, depending on shift. If unknown, use weighted average. This value is the weighted average of facility owner responses from the DOE evaluation of the Compressed Air Challenge. Facility owners with compressed air systems were surveyed detailing the number of shifts their facilities operated.} \]

<table>
<thead>
<tr>
<th>Shift</th>
<th>Hours</th>
<th>Distribution of Facilities by Hours of Operation$^{831}$</th>
<th>Weighted Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Shift</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 AM – 3 PM, weekdays, minus some holidays and scheduled down time</td>
<td>1,976</td>
<td>16%</td>
<td>316</td>
</tr>
<tr>
<td>Two Shifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 AM – 11 PM, weekdays, minus some holidays and scheduled down time</td>
<td>3,952</td>
<td>23%</td>
<td>909</td>
</tr>
<tr>
<td>Three Shifts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours per day, weekdays, minus some holidays and scheduled down time</td>
<td>5,928</td>
<td>25%</td>
<td>1,482</td>
</tr>
<tr>
<td>Four Shifts or Continual Operation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours per day, 7 days a week minus some holidays and scheduled down time</td>
<td>8,320</td>
<td>36%</td>
<td>2,995</td>
</tr>
<tr>
<td>Total weighted average</td>
<td></td>
<td></td>
<td>5,702</td>
</tr>
</tbody>
</table>

\[ \text{CFM} = \text{Cubic feet per minute, rate of airflow through the dryer.} \]

---

828 Engineering judgement, based on the assumption that on average, compressed air systems will operate at 50\% capacity.
831 DOE evaluation of the Compressed Air Challenge, section 2.1.5 Facility Operating Schedules.
= Assume 50% of actual rated capacity.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh / \text{HOURS} * \text{CF} \]

Where:

\[ \text{CF} = 0.95 \]

**NATURAL GAS ENERGY SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-CPA-CADR-V01-160601**

**REVIEW DEADLINE: 1/1/2023**
4.8 Miscellaneous End Use

4.8.1 Pump Optimization

**DESCRIPTION**

Pump improvements can be done to optimize the design and control of centrifugal water pumping systems, including water solutions with freeze protection up to 15% concentration by volume. Other fluid and gas pumps cannot use this measure calculation. The measurement of energy and demand savings for commercial and industrial applications will vary with the type of pumping technology, operating hours, efficiency, and existing and proposed controls. Depending on the specific application slowing the pump, trimming or replacing the impeller may be suitable options for improving pumping efficiency. Pumps up to 40 HP are allowed to use this energy savings calculation. Larger motors should use a custom calculation (which may result in larger savings that this measure would claim).

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the efficient equipment is proven to be an optimized centrifugal pumping system meeting the applicable program efficiency requirements:

- Pump balancing valves no more than 15% throttled
- Balancing valves on at least one load 100% open.

**DEFINITION OF BASELINE EQUIPMENT**

In order for this characterization to apply, the baseline equipment is assumed to be the existing pumping system including existing controls and sequence of operations.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 10 years.\(^{832}\)

**DEEMED MEASURE COST**

The incremental capital cost for this measure can vary considerably depending upon the strategy employed to achieve the required efficiency levels and should be determined on a site-specific basis.

**DEEMED O&M COST ADJUSTMENTS**

N/A

**COINCIDENCE FACTOR**

The summer peak coincidence factor for this measure is assumed to be 38\%\(^{833}\).

---


\(^{833}\) Summer Peak Coincidence Factor has been preserved from the “Technical Reference Manual” (TRM) for Ohio Senate Bill 221 Energy Efficiency and Conservation Program and 09-512-GE-UNC,“ October 15, 2009. This is likely a conservative estimate, but is recommended for further study (as stated in the OH State TRM, page 269)
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = (\text{HP}_{\text{motor}} \times 0.746 \times \text{LF} / \eta_{\text{motor}}) \times \text{HOURS} \times \text{ESF} \]

Where:

- \text{HP}_{\text{motor}} = \text{Installed nameplate motor horsepower}
- \text{LF} / \eta_{\text{motor}} = \text{Combined as a single factor since efficiency is a function of load}
- 0.746 = \text{Conversion factor from horse-power to kW (kW/hp)}
- \eta_{\text{motor}} = \text{Motor efficiency at pump operating conditions}
- \text{HOURS} = \text{Annual operating hours of the pump}
- \text{ESF} = \text{Energy Savings Factor; assume a value of 15\%}^{835}.

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[ \Delta \text{kW} = (\text{HP}_{\text{motor}} \times 0.746 \times (\text{LF} / \eta_{\text{motor}})) \times \text{ESF} \times \text{CF} \]

Where:

- \text{CF} = \text{Summer Coincident Peak Factor for measure}

NATURAL GAS ENERGY SAVINGS

N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

---


835 Published estimates of typical pumping efficiency improvements range from 5 to 40\%. For analysis purposes, assume 15\%.

MEASURE CODE: CI-MSC-PMPO-V01-150601

REVIEW DEADLINE: 1/1/2022
4.8.2 Roof Insulation for C&I Facilities

**DESCRIPTION**

Energy and demand saving are realized through reductions in the building cooling and heating loads. This measure was developed to be applicable to the following program types: RF and NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient condition is above code and should be determined by the program.

**DEFINITION OF BASELINE EQUIPMENT**

The retrofit baseline condition is adopted from Ohio Energy Technical Reference Manual and expanded to cover all type of commercial buildings in the state of Illinois as follows.

For retrofits, the R-value for the entire assembly:

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Retrofit Assembly R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>13.5</td>
</tr>
<tr>
<td>Assisted Living</td>
<td>13.5</td>
</tr>
<tr>
<td>College</td>
<td>13.5</td>
</tr>
<tr>
<td>Convenience Store</td>
<td>13.5</td>
</tr>
<tr>
<td>Elementary School</td>
<td>13.5</td>
</tr>
<tr>
<td>Garage</td>
<td>13.5</td>
</tr>
<tr>
<td>Grocery</td>
<td>13.5</td>
</tr>
<tr>
<td>Healthcare Clinic</td>
<td>13.5</td>
</tr>
<tr>
<td>High School</td>
<td>13.5</td>
</tr>
<tr>
<td>Hospital</td>
<td>13.5</td>
</tr>
<tr>
<td>Hotel/Motel</td>
<td>13.5</td>
</tr>
<tr>
<td>Manufacturing Facility</td>
<td>12</td>
</tr>
<tr>
<td>MF - High Rise</td>
<td>13.5</td>
</tr>
<tr>
<td>MF - Mid Rise</td>
<td>13.5</td>
</tr>
<tr>
<td>Movie Theater</td>
<td>13.5</td>
</tr>
<tr>
<td>Office - High Rise</td>
<td>13.5</td>
</tr>
<tr>
<td>Office - Low Rise</td>
<td>13.5</td>
</tr>
<tr>
<td>Office - Mid Rise</td>
<td>13.5</td>
</tr>
<tr>
<td>Religious Building</td>
<td>13.5</td>
</tr>
<tr>
<td>Restaurant</td>
<td>13.5</td>
</tr>
<tr>
<td>Retail - Department Store</td>
<td>13.5</td>
</tr>
<tr>
<td>Retail - Strip Mall</td>
<td>13.5</td>
</tr>
<tr>
<td>Warehouse</td>
<td>12</td>
</tr>
<tr>
<td>Unknown</td>
<td>13.5</td>
</tr>
</tbody>
</table>

For new construction use R-value from IECC 2012 or ASHRAE – 90.1 – 2010, or use IECC 2015 or ASHRAE – 90.1 – 2013, depending on the IECC in effect on the date of the building permit (if unknown assume IECC 2015).

**R-Values: ASHRAE – 90.1 – 2010**
**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure expected useful life (EUL) is assumed to be 20 years per DEER 2008. This is consistent with SDG&E’s 9th Year Measure Retrofit Study (1996 & 1997 Residential Weatherization Programs), CPUC’s Energy Efficiency Policy Manual v.2, and GDS’s Measure Life Report Residential and Commercial/Industrial Lighting and HVAC Measures (June 2007).
DEEMED MEASURE COST

Per the W017 Itron California Measure Cost Study\(^{836}\), the material cost for R-30 insulation is $0.59 per square foot. The installation cost is $0.81 per square foot. The total measure cost, therefore, is $1.40 per square foot of insulation installed. However, the actual cost should be used when available.

LOADSHAPE

Loadshape C03: Commercial Cooling

COINCIDENCE FACTOR

\[
\begin{align*}
\text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)} \\
&= 91.3\% \quad ^{837} \\
\text{CF}_{\text{PJM}} &= \text{PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)} \\
&= 47.8\% \quad ^{838}
\end{align*}
\]

Algorithm

CALCULATION OF ENERGY SAVINGS

Electric energy savings is calculated as the sum of energy saved when cooling the building and energy saved when heating the building

\[
\Delta \text{kWh} = \Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}
\]

If central cooling, the electric energy saved in annual cooling due to the added insulation is

\[
\Delta \text{kWh}_{\text{cooling}} = \left((1/\text{R}_{\text{existing}}) - (1/\text{R}_{\text{new}})\right) \times \text{Area} \times \text{EFLH}_{\text{cooling}} \times \Delta T_{\text{AVG,cooling}} / 1,000 / \eta_{\text{cooling}}
\]

Where:

- \(\text{R}_{\text{existing}}\) = Roof heat loss coefficient with existing insulation [(hr-\(^0\)F-ft\(^2\))/Btu]
- \(\text{R}_{\text{new}}\) = Roof heat loss coefficienty with new insulation [(hr-\(^0\)F-ft\(^2\))/Btu]
- \(\text{Area}\) = Area of the roof surface in square feet. Assume 1000 sq ft for planning.
- \(\text{EFLH}_{\text{cooling}}\) = Equivalent Full Load Hours for Cooling [hr] are provided in Section 4.4, HVAC end use
- \(\Delta T_{\text{AVG,cooling}}\) = Average temperature difference [\(^0\)F] during cooling season between outdoor air temperature and assumed 75\(^0\)F indoor air temperature

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>(\text{OA}_{\text{AVG,cooling}}) (^{\circ}\text{F}) (^{839})</th>
<th>(\Delta T_{\text{AVG,cooling}}) (^{\circ}\text{F})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>81</td>
<td>6</td>
</tr>
</tbody>
</table>

\(^{836}\) Measure costs are from the W017 Itron California Measure Cost Study, accessed via http://www.energydataweb.com/cpuc/search.aspx. The data is provided in a file named “MCS Results Matrix – Volume I”.

\(^{837}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

\(^{838}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

### Climate Zone (City based upon) OA AVG,cooling [°F] \( \Delta T \text{ AVG,cooling [°F]} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>OA AVG,cooling [°F]</th>
<th>( \Delta T \text{ AVG,cooling [°F]} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (Chicago)</td>
<td>81</td>
<td>6</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>81</td>
<td>6</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>82</td>
<td>7</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>82</td>
<td>7</td>
</tr>
</tbody>
</table>

1,000 = Conversion from Btu to kBtu

\( \eta_{\text{cooling}} \) = Seasonal energy efficiency ratio (SEER) of cooling system (kBtu/kWh). Use actual if possible, if unknown and for planning purposes assume the following:

<table>
<thead>
<tr>
<th>Year Equipment was Installed</th>
<th>SEER estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>After 2006</td>
<td>13</td>
</tr>
</tbody>
</table>

If the building is heated with electric heat (resistance or heat pump), the electric energy saved in annual heating due to the added insulation is:

\[
\Delta \text{kWh,heating} = \left( \frac{1}{R_{\text{existing}}} - \left( \frac{1}{R_{\text{new}}} \right) \right) \times \text{Area} \times \text{EFLH}_{\text{heating}} \times \Delta \text{T AVG,heating} / 3,412 / \eta_{\text{heating}}
\]

Where:

- \( \text{EFLH}_{\text{heating}} \) = Equivalent Full Load Hours for Heating [hr] are provided in Section 4.4, HVAC end use
- \( \Delta \text{T AVG,heating} \) = Average temperature difference [°F] during heating season between outdoor air temperature and assumed 55°F heating base temperature

3,142 = Conversion from Btu to kWh.

\( \eta_{\text{heating}} \) = Efficiency of heating system. Use actual efficiency. If not available refer to default table below.

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \eta_{\text{Heat}} ) (Effective COP Estimate) (HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>

If the building is heated with a gas furnace, there will be some electric savings in heating the building attributed to extra insulation since the furnace fans will run less.

---


\[ \Delta k_{\text{Wh,heating}} = \Delta \text{Therms} \times F_e \times 29.3 \]

Where:
- \( \Delta \text{Therms} \) = Gas savings calculated with equation below.
- \( F_e \) = Percentage of heating energy consumed by fans, assume 3.14%
- 29.3 = Conversion from therms to kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = (\Delta k_{\text{Wh,cooling}} / EFLH_{\text{cooling}}) \times CF \]

Where:
- \( EFLH_{\text{cooling}} \) = Equivalent full load hours of air conditioning are provided in Section 4.4, HVAC end use
- \( CF_{SSP} \) = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)
  - 91.3\% \(^{841}\)
- \( CF_{PJM} \) = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)
  - 47.8\% \(^{842}\)

**NATURAL GAS SAVINGS**

If building uses a gas furnace, the savings resulting from the insulation is calculated with the following formula.

\[ \Delta \text{Therms} = ((1/R_{\text{existing}}) - (1/R_{\text{new}})) \times \text{Area} \times EFLH_{\text{heating}} \times \Delta T_{AVG,heating} / 100,000 / \eta_{\text{heat}} \]

Where:
- \( R_{\text{existing}} \) = Roof heat loss coefficient with existing insulation [(hr\(^{-1}\)-°F-ft\(^2\))/Btu]
- \( R_{\text{new}} \) = Roof heat loss coefficient with new insulation [(hr\(^{-1}\)-°F-ft\(^2\))/Btu]
- \( \text{Area} \) = Area of the roof surface in square feet. Assume 1000 sq ft for planning.
- \( EFLH_{\text{heating}} \) = Equivalent Full Load Hours for Heating are provided in Section 4.4, HVAC end use
- \( \Delta T_{AVG,heating} \) = Average temperature difference [°F] during heating season (see above)
- 100,000 = Conversion from BTUs to Therms
- \( \eta_{\text{heat}} \) = Efficiency of existing furnace. Assume 0.78 for planning purposes.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

\(^{841}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year.

\(^{842}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
MEASURE CODE: CI-MSC-RINS-V02-160601

REVIEW DEADLINE: 1/1/2021
4.8.3 Computer Power Management Software

DESCRIPTION

Computer power management software is installed on a network of computers. This is software which monitors and records computer and monitor usage, as well as allows centralized control of computer power management settings.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined by the requirements listed below:

- Allow centralized control and override of computer power management settings of workstations which include both a computer monitor and CPU (i.e. a desktop or laptop computer on a distributed network)
- Be able to control on/off/sleep states on both the CPU and monitor according to the Network Administrator-defined schedules and apply power management policies to network groups
- Have capability to allow networked workstations to be remotely woken from power-saving mode (e.g. for system maintenance or power/setting adjustments)
- Have capability to detect and monitor power management performance and generate energy savings reports
- Have capability to produce system reports to confirm the inventory and performance of equipment on which the software is installed.

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

DEFINITION OF BASELINE EQUIPMENT

Baseline is defined as a computer network without software enforcing the power management capabilities in existing computers and monitors.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is five years.\(^{843}\)

DEEMED MEASURE COST

The deemed measure cost is $29 per networked computer, including labor.\(^{844}\)

LOADSHAPE

Loadshape C21: Commercial Office Equipment.

COINCIDENCE FACTOR

N/A

---

\(^{843}\) The following reference uses 10 years, however, given the rapid changes in the technology industry, there is quite a lot of uncertainty about the measure life and a more conservative value was used (i.e. half the published measure life): Table VI.1: Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2 (Northwest Energy Efficiency Alliance report #E05-136). Portland, OR: Quantec LLC.;

\(^{844}\) Work Paper WPSCNROE0003 Revision 1, Power Management Software for Networked Computers. Southern California Edison
CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta \text{kWh} = W_{\text{savings}} \times W$$

Where:

$W_{\text{savings}}$ = annual energy savings per workstation

= 200 kWh$^{845}$ for desktops, 50 kWh for laptops$^{846}$

= If unknown assume 161 kWh (based on 74% desktop and 26% laptop$^{847}$)

$W$ = number of desktop or laptop workstations controlled by the power management software

SUMMER COINCIDENT PEAK DEMAND SAVINGS

NA

NATURAL GAS SAVING

NA

WATER IMPACT DESCRIPTIONS AND CALCULATION

NA

DEEMED O&M COST ADJUSTMENT CALCULATION

Assumed to be $2/unit $^{848}$

MEASURE CODE: CI-MSC-CPMS-V01-150601

REVIEW DEADLINE: 1/1/2020

$^{845}$ Based on average energy savings/computer from the following sources: South California Edison, Work Paper WPSNRD0003 (200k Wh) Surveyor Network Energy Manager Evaluation Report, NEEA (68, 100, and 128kWh) Regional Technical Forum http://rtf.nwercouncil.org/measures/measure.asp?id=95 (200 kWh) EnergySTAR Computer Power Management Savings Calculator (~190 kWh for a mix of laptop/desktop and assuming 30% are already turned off at night) http://www.energystar.gov/ia/products/power_mgt/LowCarbonITSavingsCalc.xlsx?78c1-120e&78c1-120e


$^{847}$ Based on PY6 ComEd Computer Software Program data showing a split of 74% desktop to 26% laptop.


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4.8.4 Modulating Commercial Gas Clothes Dryer

**DESCRIPTION**
This measure relates to the installation of a two-stage modulating gas valve retrofit kit on a standard commercial non-modulating gas dryer. Commercial gas clothes dryers found in coin-operated laundromats or on-premise laundromats (hospitals, hotels, health clubs, etc.) traditionally have a single firing rate which is sized properly for the highest heat required in initial drying stages but is oversized for later drying stages requiring lesser heat. This causes the burner to cycle on/off frequently, resulting in less efficient drying and wasted gas. Replacing the single stage gas valve with a two-stage gas valve allows the firing rate to adjust to the changing heat demand, thereby reducing overall gas consumption.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**
A 30 to 250 pound capacity commercial gas dryer retrofitted with a two-stage modulating gas valve kit.

**DEFINITION OF BASELINE EQUIPMENT**
A 30 to 250 pound capacity commercial gas dryer with no modulating capabilities.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The deemed measure life for the retrofit kit is 14 years, assumed to be equal to that of a commercial gas dryer\(^{849}\).

**DEEMED MEASURE COST**
The full retrofit cost is assumed to be $700, including the material cost for the basic modulating gas valve retrofit kit ($600) and the associated labor for installation ($100)\(^{850}\).

**LOADSHAPE**
N/A

**COINCIDENCE FACTOR**
N/A

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**
N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**
N/A


**NATURAL GAS ENERGY SAVINGS**

Note: Accurately estimating dryer energy consumption is complicated and challenging due to a variety of factors that influence cycle times and characteristics and ultimately drying energy requirements. Clothing loads can vary by weight, volume, fiber composition, physical structure, and initial water content, meaning that for any given cycle drying energy requirements can differ. Additionally, dryer settings selected by the user as well as interactions with the site’s HVAC systems are known to influence dryer performance. As better information becomes available, this characterization can be modified to allow for a more site-specific estimation of savings.

\[
\Delta \text{Therms} = N_{\text{Cycles}} \times \text{SF}
\]

Where:

\( N_{\text{Cycles}} \) = Number of dryer cycles per year. Refer to the table below if this value is not directly available.

<table>
<thead>
<tr>
<th>Application</th>
<th>Cycles per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coin- Operated Laundromats</td>
<td>1,483</td>
</tr>
<tr>
<td>Multi-family Dryers</td>
<td>1,074</td>
</tr>
<tr>
<td>On-Premise Laundromats</td>
<td>3,607</td>
</tr>
</tbody>
</table>

\( \text{SF} \) = Savings factor

\( = 0.18 \) therms/cycle

If using default cycles the savings are as follows:

<table>
<thead>
<tr>
<th>Application</th>
<th>( \Delta \text{Therms} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coin- Operated Laundromats</td>
<td>267</td>
</tr>
<tr>
<td>Multi-family Dryers</td>
<td>193</td>
</tr>
<tr>
<td>On-Premise Laundromats</td>
<td>649</td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-MODD-V01-160601**

**REVIEW DEADLINE: 1/1/2023**

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852 Ibid.

853 Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program’s Commercial Dryer Modulation Retrofit Public Project Report.

854 Based on Illinois weather data, and average dryer performance for laundromat (30 to 45lb) and hotel (75 to 170 lb) dryers. See GTI Analysis.xlsx for complete derivation.


856 Ibid.

857 Average value for dryer cycles in healthcare facility, hotels, drycleaners and laundromats from tests conducted in Nicor Gas Emerging Technology Program’s Commercial Dryer Modulation Retrofit Public Project Report.
4.8.5 High Speed Clothes Washer

**DESCRIPTION**

This measure applies to the installation of clothes washers with extraction speeds of 200 g or greater, which is significantly higher than traditional hard-mount washers. Standard washer extractors in laundromats operate at speeds of 70-80\(^{858}\) g. The high-speed extraction process in the wash cycle removes more water from each compared to standard washers, reducing operating time and gas consumption of clothes dryers. Heat exposure and mechanical action are also reduced, resulting in less linen wear.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is assumed to be a clothes washer with an extraction speed of 200 g or greater, installed in a commercial laundromat.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is assumed to be a clothes washer with an extraction speed of 100 g or less, installed in a commercial laundromat.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure lifetime is assumed to be the typical lifetime of a commercial clothes washer: 7 years\(^{859}\). For early replacement measures it is assumed the existing unit would last another 2.3 years\(^{860}\).

**DEEMED MEASURE COST\(^{861}\)**

The incremental cost for time of sale is $9.70/lb capacity.

The full cost of the high speed washer for early replacement applications is $164.89/lb capacity. The deferred replacement cost of the baseline unit is $155.19/lb capacity. This future cost should be discounted to present value using the real discount rate:

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

---

\(^{858}\) “The Real Size of a Front Load Washer” [http://laundromat123.com/Laundromat_Washer_Comparison.html](http://laundromat123.com/Laundromat_Washer_Comparison.html)


\(^{860}\) Third of expected measure life.

\(^{861}\) Measure costs are based on data from a quote provided by a commercial washer distributor to Franklin Energy Services.
Algorithm

**Calculation of Savings**

**Electric Energy Savings**

N/A

**Summer Coincident Peak Demand Savings**

N/A

**Natural Gas Savings**

\[
\Delta \text{Therms} = (N \text{cycles} \times \text{Days} \times \text{Capacity} \times \text{RMC} \times \frac{h_e}{\eta_{\text{dryer}}/100,000}) \times \text{DryerUse} \times \text{LF}
\]

Where:

- \(N \text{cycles}\) = Average number of washer cycles per day
- Use values from table below, depending on application

<table>
<thead>
<tr>
<th>Application</th>
<th>(N \text{cycles})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coin-operated Laundromats</td>
<td>4.3\textsuperscript{862}</td>
</tr>
<tr>
<td>Multi-family</td>
<td>3.4\textsuperscript{863}</td>
</tr>
<tr>
<td>Hotel/Motel/Hospital</td>
<td>10.4\textsuperscript{864}</td>
</tr>
</tbody>
</table>

- **Days** = Days per year of commercial laundromat operation
  - Actual, or if unknown, assume 360 days\textsuperscript{865}

- **Capacity** = Clothes washer rated capacity (lb/cycle)\textsuperscript{866}
  - Actual

- **RMC** = Retained Moisture Content (%)\textsuperscript{867}
  - Reduction from replacing a low extraction speed washer
  - Assume 25%\textsuperscript{868}

---


\textsuperscript{865}Based on professional judgement, assuming closed on holidays.

\textsuperscript{866}Clothes washer capacity is based on weight of dry clothing.

\textsuperscript{867}The EDRO “Laundry Planning Guide” describes moisture retention as “the ratio of retained moisture weight to clean dry textile weight.” The pounds of water retained by clothing at the end of a wash cycle is calculated by multiplying Capacity (lbs of dry clothing per cycle) by RMC.

\textsuperscript{868}Using chart provided (Figure 1) and assuming a 100% nominal cotton load, the retained moisture drops from approximately 90% to 65% when a 100 g washer is replaced with a 200 g washer. Chart from “Laundry Planning Guide.” EDRO, January 2015.
Figure 1

\( h_e \) = Heat required by a dryer to evaporate 1 lb of water

= Assume 1,200 Btu/lb\(^869\)

\( \eta_{\text{dryer}} \) = Efficiency of the clothes dryer

= Actual, or if unknown, assume 60%\(^870\)

100,000 = Converts Btus to therms

DryerUse = % of washer loads dried in the field

= Assume 91%\(^871\)

---


\(^870\) “Are We Missing Energy Savings in Clothes Dryers?” Paul Bendt (Ecos), 2010


LF = Load Factor (%) to account for the pounds per washer load, as a percentage of rated capacity
= Assume 66%\textsuperscript{872}

\textbf{EXAMPLE}

For example, a clothes washer with a 14 lb/cycle capacity and installed at a coin-operated laundromat, using default assumptions, would save:

\[
\Delta \text{Therms} = (N \text{cycles} \times \text{Days} \times \text{Capacity} \times \text{RMC} \times h_e / \eta_{\text{dryer}} / 100,000) \times \text{DryerUse} \times \text{LF}
\]
\[
= (4.3 \times 360 \times 14 \times 0.25 \times 1,200 / 0.60 / 100,000) \times 0.91 \times 0.66
\]
\[
= 65 \text{ therms}
\]

\textbf{WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION}

N/A

\textbf{DEEMED O&M COST ADJUSTMENT CALCULATION}

N/A

\textbf{MEASURE CODE: CI-MSC-HSCW-V01-180101}

\textbf{REVIEW DEADLINE: 1/1/2021}

4.8.6 ENERGY STAR Computers

DESCRIPTION
This measure estimates savings for a desktop computer with ENERGY STAR (ES) Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, and ES 6.0 with 80 PLUS Platinum PSUs.

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

DEFINITION OF EFFICIENT EQUIPMENT
The efficient product is a desktop with a rating of ENERGY STAR Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, or ES 6.0 with 80 PLUS Platinum PSUs.

DEFINITION OF BASELINE EQUIPMENT
Non ENERGY STAR qualified equipment with standard efficiency power supply

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The life of this measure is 4 years.873

DEEMED MEASURE COST874
The incremental cost for an 80 Plus Desktop PSU is $5.
The incremental cost for an ENERGY STAR desktop PSU is $20.

LOADSHAPE
C21 Commercial Office Equipment

COINCIDENCE FACTOR
N/A

Algorithm

CALCULATION OF ENERGY SAVINGS875

\[ \Delta \text{kWh} = \frac{8760}{1000} \times \left( (\text{Watts}_{\text{Base,Off}} \times \% \text{Time Off}) + (\text{Watts}_{\text{Base,Sleep}} \times \% \text{Time Sleep}) + (\text{Watts}_{\text{Base,Long}} \times \% \text{Time Long}) + (\text{Watts}_{\text{Base,Short}} \times \% \text{Time Short}) \right) - \left( (\text{Watts}_{\text{Eff,Off}} \times \% \text{Time Off}) + (\text{Watts}_{\text{Eff,Sleep}} \times \% \text{Time Sleep}) + (\text{Watts}_{\text{Eff,Long}} \times \% \text{Time Long}) + (\text{Watts}_{\text{Eff,Short}} \times \% \text{Time Short}) \right) \]

Where (see assumptions in table below):

\[ \frac{8760}{1000} = \text{Converts W to kWh} \]

\[ \text{Watts}_{\text{Base,Off}} = \text{baseline equipment power in off mode} \]


875 Algorithm comes from ENERGY STAR Version 6.0 Guide
%Time Off = typical percent of time a desktop, integrated desktop or notebook is in off mode during the year

Watts Base, Sleep = baseline equipment power in sleep mode

%Time Sleep = typical percent time in sleep mode

Watts Base, Long = baseline equipment power in long idle mode

%Time Long = typical percent time in long idle mode

Watts Base, Short = baseline equipment power in short idle mode

%Time Short = typical percent time in short idle mode

Watts Eff, Off = efficient equipment power in off mode

Watts Eff, Sleep = efficient equipment power in sleep mode

Watts Eff, Long = efficient equipment power in long idle mode

Watts Eff, Short = efficient equipment power in short idle mode

### Measure Annual Mode Time (%)

<table>
<thead>
<tr>
<th>Duty cycle - Commercial</th>
<th>Off</th>
<th>Sleep</th>
<th>Long Idle</th>
<th>Short Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>876</td>
<td>45%</td>
<td>5%</td>
<td>15%</td>
<td>35%</td>
</tr>
</tbody>
</table>

### Measure Watt Draw in Mode (Watts)

<table>
<thead>
<tr>
<th>Watt Draw in Mode (Watts)</th>
<th>Off</th>
<th>Sleep</th>
<th>Long Idle</th>
<th>Short Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.88</td>
<td>2.1</td>
<td>26.5</td>
<td>27.9</td>
</tr>
<tr>
<td>ES 6.0 Desktops</td>
<td>0.55</td>
<td>1.23</td>
<td>24.66</td>
<td>26.04</td>
</tr>
<tr>
<td>ES 6.0 +20% Desktops</td>
<td>0.52</td>
<td>1.63</td>
<td>21.33</td>
<td>22.58</td>
</tr>
<tr>
<td>ES 6.0 Desktops w/ 80 PLUS Gold PSUs</td>
<td>0.50</td>
<td>1.50</td>
<td>23.08</td>
<td>24.38</td>
</tr>
<tr>
<td>ES 6.0 Desktops w/ 80 PLUS Platinum PSUs</td>
<td>0.50</td>
<td>1.50</td>
<td>22.19</td>
<td>23.44</td>
</tr>
</tbody>
</table>

Calculated energy consumption in each mode, and savings provided below:

<table>
<thead>
<tr>
<th>Measure TEC by Mode (kWh) Commercial</th>
<th>Off</th>
<th>Sleep</th>
<th>Long Idle</th>
<th>Short Idle</th>
<th>TEC (kWh/yr)</th>
<th>Savings (kWh/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>3.5</td>
<td>0.9</td>
<td>34.8</td>
<td>85.5</td>
<td>124.8</td>
<td>N/A</td>
</tr>
<tr>
<td>ES 6.0 Desktops</td>
<td>2.2</td>
<td>0.5</td>
<td>32.4</td>
<td>79.9</td>
<td>115.0</td>
<td>9.8</td>
</tr>
<tr>
<td>ES 6.0 +20% Desktops</td>
<td>2.0</td>
<td>0.7</td>
<td>28.0</td>
<td>69.2</td>
<td>100.0</td>
<td>24.7</td>
</tr>
<tr>
<td>ES 6.0 Desktops w/ 80 PLUS Gold PSUs</td>
<td>2.0</td>
<td>0.7</td>
<td>30.3</td>
<td>74.7</td>
<td>107.7</td>
<td>17.1</td>
</tr>
<tr>
<td>ES 6.0 Desktops w/ 80 PLUS Platinum PSUs</td>
<td>2.0</td>
<td>0.7</td>
<td>29.2</td>
<td>71.9</td>
<td>103.7</td>
<td>21.1</td>
</tr>
</tbody>
</table>

Savings calculations can be referenced in “ENERGY STAR Desktop Analysis.xlsx”

---


879 Analysis of current DT I2 category desktops in ES v6.0 QPL, passing with > 20% margin.

880 80 PLUS program savings calculator, additional 6.4% savings over ES v6.0 Bronze PSU levels. Based on program measurements, available at [http://www.80plus.org](http://www.80plus.org).

881 80 PLUS program savings calculator, additional 10% savings over ES v6.0 Bronze PSU levels.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \frac{(Watts_{\text{Base}} - Watts_{\text{Eff}})}{1000} \times CF \]

Where:

- \( Watts_{\text{Base}} \) = Assumed average baseline wattage during peak period (see table below)
- \( Watts_{\text{Eff}} \) = Assumed average efficient wattage during peak period (see table below)
- \( CF \) = Summer Peak Coincidence Factor = 1.0

Calculated average demand during peak period, and savings provided below:

<table>
<thead>
<tr>
<th>Measure TEC by Mode (kWh) Commercial</th>
<th>TEC (watts)</th>
<th>Demand Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>25.2</td>
<td>N/A</td>
</tr>
<tr>
<td>ES 6.0 Desktops</td>
<td>23.4</td>
<td>0.0018</td>
</tr>
<tr>
<td>ES 6.0 +20% Desktops</td>
<td>20.3</td>
<td>0.0048</td>
</tr>
<tr>
<td>ES 6.0 Desktops w/ 80 PLUS Gold PSUs</td>
<td>21.9</td>
<td>0.0032</td>
</tr>
<tr>
<td>ES 6.0 Desktops w/ 80 PLUS Platinum PSUs</td>
<td>21.1</td>
<td>0.0041</td>
</tr>
</tbody>
</table>

Savings calculations can be referenced in “ENERGY STAR Desktop Analysis.xlsx”

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-COMP-V01-180101**

**REVIEW DEADLINE: 1/1/2020**

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It assumed that computers will not be off during peak period, and that the weighting of sleep, long idle and short idle during peak hours is consistent with the whole year. Wattage assumptions are weighted accordingly and coincidence factor is thus assumed to be 1.0 — see “ENERGY STAR Desktop Analysis.xlsx” for calculation.
4.8.7 Advanced Power Strip – Tier 1 Commercial

DESCRIPTION

This measure relates to Advanced Power Strips – Tier 1 which are multiplug power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (e.g. a desk workstation) can be reduced. In a commercial office space, savings generally occur during off-hours, when connected equipment continues to consume electricity while in standby mode or when off. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it.

This measure was developed to be applicable to the following program types: DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is an advanced power strip with a load-sensing master plug and at least two controlled plugs.

DEFINITION OF BASELINE EQUIPMENT

The assumed baseline is a standard power strip with surge protection that does not control connected loads.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years. 883

DEEMED MEASURE COST

For direct install the actual full install cost (including labor) and for kits the full equipment cost should be used.

LOADSHAPE

Loadshape C47 – Standby Losses – Commercial Office 884

COINCIDENCE FACTOR

N/A due to no savings attributable to standby losses between 1 and 5 PM.

---

883 This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

884 Loadshapes were calculated from empirical studies and compared to the existing loadshape in Volume 1, Table 3.5. The studies were:


**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta \text{kWh}^{885} = ((W_{\text{wkday}} \times (h_{\text{wkday}} - h_{\text{wkday-open}})) + kW_{\text{wkend}} \times (h_{\text{wkend}} - h_{\text{wkend-open}})) \times \text{weeks/year} \times \text{ISR}
\]

Where:

- \( W_{\text{wkday}} \) = Standby power consumption of connected electronics on weekday off-hours. If unknown, assume 0.0315 kW.
- \( kW_{\text{wkend}} \) = Standby power consumption of connected electronics on weekend off-hours. If unknown, assume 0.00617 kW.
- \( h_{\text{wkday}} \) = total hours during the work week (Monday 7:30 AM to Friday 5:30 PM) = 106
- \( h_{\text{wkend}} \) = total hours during the weekend (Friday 5:30 PM to Monday 7:30 AM) = 62
- \( h_{\text{wkday-open}} \) = hours the office is open during the work week. If unknown, assume 50 hours.
- \( h_{\text{wkend-open}} \) = hours the office is open during the weekend. If unknown, assume 0 hours.
- \( \text{weeks/year} \) = number of weeks per year = 52.2
- \( \text{ISR} \) = In Service Rate

= Assume 0.969 for commercial Direct Install application

For example, an office open 9 hours per day (45 hours per week) on weekdays and 4 hours on Saturday:

\[\Delta \text{kWh} = ((0.0315 \times (106 - 45) + 0.00617 \times (62 - 4) \times 52.2) \times 0.969 = 115 \text{ kWh}\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A due to no savings attributable to standby losses between 1 and 5 PM.

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

---

885 Savings algorithm reconstructed from weekday and weekend savings information in Sheppy *et. al*, and verified against savings in Acker *et. al* and savings in: BPA, “Smart Power Strip Energy Savings Evaluation: Ross Complex,” (2011). Office stations are assumed to have zero or minimal standby losses during normal operating hours. Method shown in “Commercial Tier 1 APS Calculations – IL TRM.xlsx”.

886 Based upon review of the PY2 and PY3 ComEd Direct Install Residential program surveys. This value could be modified based upon commercial application evaluation.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-APSC-V01-180101

REVIEW DEADLINE: 1/1/2020
4.8.8 High Efficiency Transformer

DESCRIPTION

Distribution transformers are used in commercial and industrial applications to step down power from distribution voltage to be used in HVAC or process loads (220V or 480V) or to serve plug loads (120V). Distribution transformers that are more efficient than the required minimum federal standard efficiency qualify for this measure. If there is no specific standard efficiency requirement, the transformer does not qualify (because we cannot define a reasonable baseline). For example, although the federal standards increased the minimum required efficiency in 2016, most transformers with a NEMA premium or CEE Tier 2 rating will still achieve energy conservation. Standards are defined for low-voltage dry-type distribution transformers (up to 333kVA single-phase and 1000kVA 3-phase), liquid-immersed distribution transformers (up to 833kVA single-phase and 2500kVA 3-phase), and medium-voltage dry-type distribution transformers (up to 833kVA single-phase and 2500kVA 3-phase).

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Any transformer that is more efficient than the federal minimum standard. This includes CEE Tier II (single or three phase) and most NEMA premium efficiency rated products.

DEFINITION OF BASELINE EQUIPMENT

A transformer that meets the minimum federal efficiency requirement should be used as the baseline to calculate savings. Standards are developed by the Department of Energy and published in the Federal Register 10CFR 431.887

(a) Low-Voltage Dry-Type Distribution Transformers.

(2) The efficiency of a low-voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Low-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

<table>
<thead>
<tr>
<th>kVA</th>
<th>Efficiency (%)</th>
<th>kVA</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>97.70</td>
<td>15</td>
<td>97.89</td>
</tr>
<tr>
<td>25</td>
<td>98.00</td>
<td>30</td>
<td>98.23</td>
</tr>
<tr>
<td>37.5</td>
<td>98.20</td>
<td>45</td>
<td>98.40</td>
</tr>
<tr>
<td>50</td>
<td>98.30</td>
<td>75</td>
<td>98.60</td>
</tr>
<tr>
<td>75</td>
<td>98.50</td>
<td>112.5</td>
<td>98.74</td>
</tr>
<tr>
<td>100</td>
<td>98.60</td>
<td>150</td>
<td>98.83</td>
</tr>
<tr>
<td>167</td>
<td>98.70</td>
<td>225</td>
<td>98.94</td>
</tr>
<tr>
<td>250</td>
<td>98.80</td>
<td>300</td>
<td>99.02</td>
</tr>
<tr>
<td>333</td>
<td>98.90</td>
<td>500</td>
<td>99.14</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>99.23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1000</td>
<td>99.28</td>
<td></td>
</tr>
</tbody>
</table>

(b) Liquid-Immersed Distribution Transformers.

(2) The efficiency of a liquid-immersed distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA rating in the table below. Liquid-immersed distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

<table>
<thead>
<tr>
<th>Single-phase</th>
<th>Three-phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>kVA</td>
<td>Efficiency (%)</td>
</tr>
<tr>
<td>10</td>
<td>98.70</td>
</tr>
<tr>
<td>15</td>
<td>98.82</td>
</tr>
<tr>
<td>25</td>
<td>98.95</td>
</tr>
<tr>
<td>37.5</td>
<td>99.05</td>
</tr>
<tr>
<td>50</td>
<td>99.11</td>
</tr>
<tr>
<td>75</td>
<td>99.19</td>
</tr>
<tr>
<td>100</td>
<td>99.25</td>
</tr>
<tr>
<td>167</td>
<td>99.33</td>
</tr>
<tr>
<td>250</td>
<td>99.39</td>
</tr>
<tr>
<td>333</td>
<td>99.43</td>
</tr>
<tr>
<td>500</td>
<td>99.49</td>
</tr>
<tr>
<td>667</td>
<td>99.52</td>
</tr>
<tr>
<td>833</td>
<td>99.55</td>
</tr>
<tr>
<td>2500</td>
<td></td>
</tr>
</tbody>
</table>

(c) **Medium-Voltage Dry-Type Distribution Transformers.**

(2) The efficiency of a medium- voltage dry-type distribution transformer manufactured on or after January 1, 2016, shall be no less than that required for their kVA and BIL rating in the table below. Medium-voltage dry-type distribution transformers with kVA ratings not appearing in the table shall have their minimum efficiency level determined by linear interpolation of the kVA and efficiency values immediately above and below that kVA rating.

<table>
<thead>
<tr>
<th>Single-phase</th>
<th>Three-phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>kVA</td>
<td>BIL* 20-45 kV Efficiency (%)</td>
</tr>
<tr>
<td>15</td>
<td>98.10</td>
</tr>
<tr>
<td>25</td>
<td>98.33</td>
</tr>
<tr>
<td>37.5</td>
<td>98.49</td>
</tr>
<tr>
<td>50</td>
<td>98.60</td>
</tr>
<tr>
<td>75</td>
<td>98.73</td>
</tr>
<tr>
<td>100</td>
<td>98.82</td>
</tr>
<tr>
<td>167</td>
<td>98.96</td>
</tr>
<tr>
<td>250</td>
<td>99.07</td>
</tr>
<tr>
<td>333</td>
<td>99.14</td>
</tr>
<tr>
<td>500</td>
<td>99.22</td>
</tr>
</tbody>
</table>
### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

30 years\(^{888}\)

### DEEMED MEASURE COST

Actual incremental costs should be used.

### LOADSHAPE

Use custom loadshape based on application; default loadshape is Loadshape C53 – Flat.

### COINCIDENCE FACTOR

Coincidence Factor for distribution transformers is 1.0 by definition. By including the load factor in the demand savings calculation, the load profile is accounted for.

### Calculation of Energy Savings

Savings are determined by metering equipment.

#### Electric Energy Savings

\[ \Delta \text{kWh} = \text{Losses}_{\text{base}} - \text{Losses}_{\text{EE}} \]

Where:

\[ \text{Losses}_{\text{base}} = \text{PowerRating} \times \text{LF} \times \text{PF} \times \left( \frac{1}{\text{EFF}_{\text{base}}} - 1 \right) \times 8766 \]

\[ \text{Losses}_{\text{EE}} = \text{PowerRating} \times \text{LF} \times \text{PF} \times \left( \frac{1}{\text{EFF}_{\text{EE}}} - 1 \right) \times 8766 \]

- \text{PowerRating} = \text{kVA rating of the transformer (in units of kVA)}
- \text{EFF}_{\text{base}} = \text{baseline total efficiency rating of federal minimum standard transformer (refer to baseline tables above based on kVA, voltage, and type of transformer)}

---

EFF\textsubscript{EE} = actual total efficiency rating of the transformer as calculated by the appropriate DOE test method\textsuperscript{889}

LF = Load Factor for the transformer. Ratio of average transformer load to peak load rating over a period of one year. Use actual load factor for the network segment served based on historical data. If unknown, use 22\% for commercial load and 45\% for industrial load.\textsuperscript{890}

PF = Power Factor for the load being served by the transformer. Ratio of real power to apparent power supplied to the transformer. Use actual power factor for the network segment served. If unknown, use 1.0 (unity) by default.\textsuperscript{891}

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \text{PowerRating} \times LF \times PF \times \left( \frac{1}{Eff\textsubscript{base}} - \frac{1}{Eff\textsubscript{EE}} \right) \]

Variables as provided above.

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: CI-MSC-TRNS-V01-180101**

**REVIEW DEADLINE: 1/1/2021**

---


\textsuperscript{890} Guidelines on The Calculation and Use of Loss Factors, Electric Authority, Te Mana Hiko, February 14, 2013

4.8.9 High Frequency Battery Chargers

**DESCRIPTION**

This measure applies to industrial high frequency battery chargers, used for industrial equipment such as forklifts, replacing existing SCR (silicon controlled rectifier) or ferroresonant charging technology. High frequency battery chargers have a greater system efficiency.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

High frequency battery charger systems with minimum Power Conversion Efficiency of 90% and a minimum 8-hour shift operation five days per week.

**DEFINITION OF BASELINE EQUIPMENT**

SCR or ferroresonant battery charger systems with minimum 8-hour shift operation five days per week.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

15 years

**DEEMED MEASURE COST**

The deemed incremental measure cost is $400

**LOADSHAPE**

Loadshape C14 - Indust. 1-shift (8/5) (e.g., comp. air, lights)
Loadshape C15 - Indust. 2-shift (16/5) (e.g., comp. air, lights)
Loadshape C16 - Indust. 3-shift (24/5) (e.g., comp. air, lights)
Loadshape C17 - Indust. 4-shift (24/7) (e.g., comp. air, lights)

**COINCIDENCE FACTOR**

The coincidence factor is assumed to be 0.0 for 1 and 2-shift operation and 1.0 for 3 and 4-shift operation.

---

892 Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 45
893 Suzanne Foster Porter et al., “Analysis of Standards Options for Battery Charger Systems”, (PG&E, 2010), 42
Algorithm

**Electric Energy Savings**

\[ \Delta kWh = (\text{CAP} \times \text{DOD}) \times \text{CHG} \times (\text{CR}_B / \text{PC}_B - \text{CR}_{EE} / \text{PC}_{EE}) \]

Where:

- **CAP** = Capacity of Battery
  - Use actual battery capacity, otherwise use a default value of 35 kWh\(^{895}\)
- **DOD** = Depth of Discharge
  - Use actual depth of discharge, otherwise use a default value of 80%. \(^{896}\)
- **CHG** = Number of Charges per year
  - Use actual number of annual charges, if unknown use values below based on the type of operations\(^{897}\)

<table>
<thead>
<tr>
<th>Standard Operations</th>
<th>Number of Charges per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-shift (8 hrs/day – 5 days/week)</td>
<td>520</td>
</tr>
<tr>
<td>2-shift (16 hrs/day – 5 days/week)</td>
<td>1040</td>
</tr>
<tr>
<td>3-shift (24 hrs/day – 5 days/week)</td>
<td>1560</td>
</tr>
<tr>
<td>4-shift (24 hrs/day – 7 days/week)</td>
<td>2184</td>
</tr>
</tbody>
</table>

- **CR\(_B\)** = Baseline Charge Return Factor
  - 1.2486\(^{898}\)
- **PC\(_B\)** = Baseline Power Conversion Efficiency
  - 0.84\(^{899}\)
- **CR\(_{EE}\)** = Efficient Charge Return Factor
  - 1.107\(^{900}\)
- **PC\(_{EE}\)** = Efficient Power Conversion Efficiency
  - 0.89\(^{901}\)

Default savings using defaults provided above are provided below:

<table>
<thead>
<tr>
<th>Standard Operations</th>
<th>(\Delta kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-shift (8 hrs/day – 5 days/week)</td>
<td>3,531</td>
</tr>
<tr>
<td>2-shift (16 hrs/day – 5 days/week)</td>
<td>7,061</td>
</tr>
<tr>
<td>3-shift (24 hrs/day – 5 days/week)</td>
<td>10,592</td>
</tr>
</tbody>
</table>


\(^{897}\) Number of charges is derived from the following reference and adjusted to the hours and days of the different types of shift operations. These values are based on an estimated 2-charge per 8-hour workday. See reference file Ryan Matley, “Measuring Energy Efficiency Improvements in Industrial Battery Chargers”, (ESL-IE-09-05-32, Energy Technology Conference, New Orleans, LA, May 12-15, 2009), 4


\(^{899}\) Ibid.

\(^{900}\) Ibid.

\(^{901}\) Ibid.
### SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[ \Delta kW = (PF_B/PC_B - PF_EE/PC_EE) \times Volts_{DC} \times Amps_{DC} / 1000 \times CF \]

Where:
- \( PF_B \) = Power factor of baseline charger = 0.9095\(^{902} \)
- \( PF_EE \) = Power factor of high frequency charger = 0.9370\(^{903} \)
- \( Volts_{DC} \) = Actual DC rated voltage of charger (assumed baseline charger is replaced with same rated high frequency unit)
  - Use actual battery DC voltage rating, otherwise use a default value of 48 volts.\(^{904} \)
- \( Amps_{DC} \) = Actual DC rated amperage of charger (assumed baseline charger is replaced with same rated high frequency unit)
  - Use actual battery DC ampere rating, otherwise use a default value of 81 amps.\(^{905} \)
- 1,000 = watt to kilowatt conversion factor
- \( CF \) = Summer Coincident Peak Factor for this measure
  - 0.0 (for 1 and 2-shift operation)\(^{906} \)
  - 1.0 (for 3 and 4-shift operation)\(^{907} \)
- Other variables as provided above.

Default savings using defaults provided above are provided below:

<table>
<thead>
<tr>
<th>Standard Operations</th>
<th>( \Delta kW )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-shift (8 hrs/day – 5 days/week)</td>
<td>0</td>
</tr>
<tr>
<td>2-shift (16 hrs/day – 5 days/week)</td>
<td>0</td>
</tr>
<tr>
<td>3-shift (24 hrs/day – 5 days/week)</td>
<td>0.1165</td>
</tr>
<tr>
<td>4-shift (24 hrs/day – 7 days/week)</td>
<td>0.1165</td>
</tr>
</tbody>
</table>

### NATURAL GAS SAVINGS

N/A

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

\(^{902}\) Ibid.

\(^{903}\) Ibid.


\(^{907}\) Ibid.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: CI-MSC-BACH-V01-180101

REVIEW DEADLINE: 1/1/2021
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VOLUME 4: CROSS-CUTTING MEASURES AND ATTACHMENTS
Volume 3: Residential Measures

5.1 Appliances End Use

5.1.1 ENERGY STAR Air Purifier/Cleaner

DESCRIPTION
An air purifier (cleaner) meeting the efficiency specifications of ENERGY STAR is purchased and installed in place of a model meeting the current federal standard.

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

DEFINITION OF EFFICIENT EQUIPMENT
The efficient equipment is defined as an air purifier meeting the efficiency specifications of ENERGY STAR as provided below.

- Must produce a minimum 50 Clean Air Delivery Rate (CADR) for Dust\(^1\) 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)

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is assumed to be a conventional unit\(^2\).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The measure life is assumed to be 9 years\(^3\).

DEEMED MEASURE COST
The incremental cost for this measure is $70.\(^4\)

LOADSHAPE
Loadshape C53 - Flat

COINCIDENCE FACTOR
The summer peak coincidence factor for this measure is assumed to be 100 % (the unit is assumed to be always on).

\(^1\) Measured according to the latest ANSI/AHAM AC-1 (AC-1) Standard
\(^2\) As defined as the average of non-ENERGY STAR products found in EPA research, 2011, ENERGY STAR Qualified Room Air Cleaner Calculator.
\(^3\) ENERGY STAR Qualified Room Air Cleaner Calculator.
\(^4\) Ibid
Algorithm

Calculation of Savings

Electric Energy Savings

\[ \Delta kWh = kWh_{base} - kWh_{ESTAR} \]

Where:
- \( kWh_{base} \) = Baseline kWh consumption per year\(^5\)
  - see table below
- \( kWh_{ESTAR} \) = ENERGY STAR kWh consumption per year\(^6\)
  - see table below

<table>
<thead>
<tr>
<th>Clean Air Delivery Rate (CADR)</th>
<th>CADR used in calculation (midpoint)</th>
<th>Baseline Unit Energy Consumption (kWh/year)</th>
<th>Unit Energy Consumption (kWh/year)</th>
<th>( \Delta kWh )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CADR 51-100</td>
<td>75</td>
<td>441</td>
<td>148</td>
<td>293</td>
</tr>
<tr>
<td>CADR 101-150</td>
<td>125</td>
<td>733</td>
<td>245</td>
<td>488</td>
</tr>
<tr>
<td>CADR 151-200</td>
<td>175</td>
<td>1025</td>
<td>342</td>
<td>683</td>
</tr>
<tr>
<td>CADR 201-250</td>
<td>225</td>
<td>1317</td>
<td>440</td>
<td>877</td>
</tr>
<tr>
<td>CADR Over 250</td>
<td>300</td>
<td>1755</td>
<td>586</td>
<td>1169</td>
</tr>
</tbody>
</table>

Summer Coincident Peak Demand Savings

\[ \Delta kW = \Delta kWh/\text{Hours} \times \text{CF} \]

Where:
- \( \Delta kWh \) = Gross customer annual kWh savings for the measure
- \( \text{Hours} \) = Average hours of use per year
  - 5844 hours\(^7\)
- \( \text{CF} \) = Summer Peak Coincidence Factor for measure
  - 66.7%\(^8\)

<table>
<thead>
<tr>
<th>Clean Air Delivery Rate</th>
<th>( \Delta kW )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CADR 51-100</td>
<td>0.033</td>
</tr>
<tr>
<td>CADR 101-150</td>
<td>0.056</td>
</tr>
<tr>
<td>CADR 151-200</td>
<td>0.078</td>
</tr>
<tr>
<td>CADR 201-250</td>
<td>0.100</td>
</tr>
<tr>
<td>CADR Over 250</td>
<td>0.133</td>
</tr>
</tbody>
</table>

\(^5\) ENERGY STAR Qualified Room Air Cleaner Calculator.
\(^6\) Ibid.
\(^7\) Consistent with ENERGY STAR Qualified Room Air Cleaner Calculator assumption of 16 hours per day (16 \* 365.25 = 5844).
\(^8\) Assumes that the purifier usage is evenly spread throughout the year, therefore coincident peak is calculated as 5844/8766 = 66.7%.
NATURAL GAS SAVINGS
N/A

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
There are no operation and maintenance cost adjustments for this measure.9

MEASURE CODE: RS-APL-ESAP-V02-160601

REVIEW DEADLINE: 1/1/2023

---

9 Some types of room air cleaners require filter replacement or periodic cleaning, but this is likely to be true for both efficient and baseline units and so no difference in cost is assumed.
5.1.2 ENERGY STAR and ENERGY STAR Most Efficient Clothes Washers

DESCRIPTION

This measure relates to the installation of a clothes washer meeting the ENERGY STAR, or ENERGY STAR Most Efficient minimum qualifications. Note if the DHW and dryer fuels of the installations are unknown (for example through a retail program) savings should be based on a weighted blend using RECS data (the resultant values (kWh, therms and gallons of water) are provided). The algorithms can also be used to calculate site specific savings where DHW and dryer fuels are known.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

Clothes washer must meet the ENERGY STAR or ENERGY STAR Most Efficient minimum qualifications, as required by the program.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is a standard sized clothes washer meeting the minimum federal baseline as of March 2015\(^\text{10}\).

<table>
<thead>
<tr>
<th>Efficiency Level</th>
<th>Top loading &gt;2.5 Cu ft</th>
<th>Front Loading &gt;2.5 Cu ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Standard</td>
<td>1.29 IMEF, 8.4 IWF</td>
<td>1.84 IMEF, 4.7 IWF</td>
</tr>
<tr>
<td>ENERGY STAR</td>
<td>2.06 IMEF, 4.3 IWF</td>
<td>2.38 IMEF, 3.7 IWF</td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</td>
<td>2.76 IMEF, 3.5 IWF</td>
<td>2.74 IMEF, 3.2 IWF</td>
</tr>
</tbody>
</table>

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 14 years\(^\text{11}\).

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR unit is assumed to be $65 and for an ENERGY STAR Most Efficient unit it is $210\(^\text{12}\).

DEEMED O&M COST ADJUSTMENTS

N/A

---


\(^{11}\) 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/clothes_washers_support_stakeholder_negotiations.html

\(^{12}\) Cost estimates are based on Navigant analysis for the Department of Energy (see CW Analysis_09092014.xls). This analysis looked at incremental cost and shipment data from manufacturers and the Association of Home Appliance Manufacturers and attempts to find the costs associated only with the efficiency improvements. The ENERGY STAR level in this analysis was made the baseline (as it is now equivalent), the CEE Tier 3 level was made ENERGY STAR and ENERGY STAR Most efficient was extrapolated based on equal rates. Note these assumptions should be reviewed as qualifying product becomes available.
LOADSHAPE

Loadshape R01 - Residential Clothes Washer

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%\textsuperscript{13}.

Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

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

   The Modified Energy Factor (MEF) includes unit operation, water heating and drying energy use:
   
   "$MEF$ is the quotient of the capacity of the clothes container, \( C \), divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, \( M \), the hot water energy consumption, \( E \), and the energy required for removal of the remaining moisture in the wash load, \( D \)$\textsuperscript{14}.

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

   \[
   IMEFSavings = \text{Capacity} \times (1/\text{IMEFbase} - 1/\text{IMEFeff}) \times N\text{cycles}
   \]

   Where

   - **Capacity** = Clothes Washer capacity (cubic feet)
     = Actual. If capacity is unknown assume 3.45 cubic feet\textsuperscript{16}
   - **IMEFbase** = Integrated Modified Energy Factor of baseline unit
     = 1.66\textsuperscript{17}
   - **IMEFeff** = Integrated Modified Energy Factor of efficient unit
     = Actual. If unknown assume average values provided below.
   - **Ncycles** = Number of Cycles per year
     = 295\textsuperscript{18}

---

\textsuperscript{13} Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
\textsuperscript{14} Definition provided on the Energy star website.
\textsuperscript{15} IMEFSavings represents total kWh only when water heating and drying are 100% electric.
\textsuperscript{16} Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/28/2014. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.
\textsuperscript{17} Weighted average IMEF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database.
\textsuperscript{18} Weighted average of 295 clothes washer cycles per year (based on 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section, state of IL: http://www.eia.gov/consumption/residential/data/2009/ If utilities have specific evaluation results providing a more appropriate assumption for single-family or multi-family homes, in a particular market, or geographical area then that should be used.
IMEFsavings is provided below based on deemed values:\(^{19}\):

<table>
<thead>
<tr>
<th>Efficiency Level</th>
<th>IMEF</th>
<th>IMEFSavings (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Standard</td>
<td>1.66</td>
<td>0.0</td>
</tr>
<tr>
<td>ENERGY STAR</td>
<td>2.26</td>
<td>163</td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</td>
<td>2.74</td>
<td>242</td>
</tr>
</tbody>
</table>

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

\[ \Delta \text{kWh} = \left[ \text{Capacity} \times \frac{1}{\text{IMEF}_{\text{base}}} \times \text{Ncycles} \times (\% \text{CW}_{\text{base}} + (\% \text{DHW}_{\text{base}} \times \% \text{Electric}_\text{DHW}) + (\% \text{Dryer}_{\text{base}} \times \% \text{Electric}_\text{Dryer})) \right] - \left[ \text{Capacity} \times \frac{1}{\text{IMEF}_{\text{eff}}} \times \text{Ncycles} \times (\% \text{CW}_{\text{eff}} + (\% \text{DHW}_{\text{eff}} \times \% \text{Electric}_\text{DHW}) + (\% \text{Dryer}_{\text{eff}} \times \% \text{Electric}_\text{Dryer})) \right] \]

Where:

- \( \% \text{CW} \) = Percentage of total energy consumption for Clothes Washer operation (different for baseline and efficient unit – see table below)
- \( \% \text{DHW} \) = Percentage of total energy consumption used for water heating (different for baseline and efficient unit – see table below)
- \( \% \text{Dryer} \) = Percentage of total energy consumption for dryer operation (different for baseline and efficient unit – see table below)

<table>
<thead>
<tr>
<th>Percentage of Total Energy Consumption(^{20})</th>
<th>%CW</th>
<th>%DHW</th>
<th>%Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>7.6%</td>
<td>31.2%</td>
<td>61.2%</td>
</tr>
<tr>
<td>ENERGY STAR</td>
<td>8.1%</td>
<td>23.4%</td>
<td>68.5%</td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</td>
<td>13.6%</td>
<td>10%</td>
<td>76.3%</td>
</tr>
</tbody>
</table>

- \( \% \text{Electric}_\text{DHW} \) = Percentage of DHW savings assumed to be electric

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Electric_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>16%(^{21})</td>
</tr>
</tbody>
</table>

- \( \% \text{Electric}_\text{Dryer} \) = Percentage of dryer savings assumed to be electric

<table>
<thead>
<tr>
<th>Dryer fuel</th>
<th>%Electric_Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
</tbody>
</table>

\(^{19}\) IMEF values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and ENERGY STAR Most Efficient product in the CEC database. See “CW Analysis_01142016.xls” for the calculation.

\(^{20}\) 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 data from DOE Life-Cycle Cost and Payback Period Excel-based analytical tool. See “CW Analysis_01142016.xls” for the calculation.

\(^{21}\) Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.
Using the default assumptions provided above, the prescriptive savings for each configuration are presented below:

<table>
<thead>
<tr>
<th></th>
<th>Electric DHW</th>
<th>Gas DHW Electric Dryer</th>
<th>Electric DHW Gas Dryer</th>
<th>Gas DHW Gas Dryer</th>
<th>Electric DHW Unknown Dryer</th>
<th>Gas DHW Unknown Dryer</th>
<th>Unknown DHW Electric Dryer</th>
<th>Unknown DHW Gas Dryer</th>
<th>Unknown DHW Unknown Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENERGY STAR</strong></td>
<td>162.7</td>
<td>77.0</td>
<td>96.0</td>
<td>10.2</td>
<td>120.0</td>
<td>34.3</td>
<td>90.7</td>
<td>24.0</td>
<td>48.0</td>
</tr>
<tr>
<td><strong>ENERGY STAR Most Efficient</strong></td>
<td>242.1</td>
<td>88.2</td>
<td>149.9</td>
<td>-4.0</td>
<td>183.1</td>
<td>29.2</td>
<td>112.8</td>
<td>20.6</td>
<td>53.8</td>
</tr>
</tbody>
</table>

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \frac{\Delta kWh}{\text{Hours}} \times CF
\]

Where:

\[
\Delta kWh = \text{Energy Savings as calculated above}
\]

\[
\text{Hours} = \text{Assumed Run hours of Clothes Washer}
\]

\[
\text{CF} = \text{Summer Peak Coincidence Factor for measure.}
\]

\[
\text{CF} = 0.038
\]

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

<table>
<thead>
<tr>
<th></th>
<th>Electric DHW</th>
<th>Gas DHW Electric Dryer</th>
<th>Electric DHW Gas Dryer</th>
<th>Gas DHW Gas Dryer</th>
<th>Electric DHW Unknown Dryer</th>
<th>Gas DHW Unknown Dryer</th>
<th>Unknown DHW Electric Dryer</th>
<th>Unknown DHW Gas Dryer</th>
<th>Unknown DHW Unknown Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENERGY STAR</strong></td>
<td>0.0210</td>
<td>0.0099</td>
<td>0.0124</td>
<td>0.0013</td>
<td>0.0155</td>
<td>0.0044</td>
<td>0.0117</td>
<td>0.0031</td>
<td>0.0062</td>
</tr>
<tr>
<td><strong>ENERGY STAR Most Efficient</strong></td>
<td>0.0312</td>
<td>0.0114</td>
<td>0.0193</td>
<td>-0.0005</td>
<td>0.0236</td>
<td>0.0038</td>
<td>0.0145</td>
<td>0.0027</td>
<td>0.0069</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**

Break out savings calculated in Step 1 of electric energy savings (MEF savings) and extract Natural Gas DHW and Natural Gas dryer savings from total savings:

\[
\Delta \text{Therm} = (\text{Capacity} \times \frac{1}{\text{IMEFbase}} \times \text{Ncycles} \times (\%\text{DHWbase} \times \%\text{Natural Gas DHW} \times R_{\text{eff}}) + (\%\text{Dryerbase} \times \%\text{Gas Dryer})) \times (\text{Capacity} \times \frac{1}{\text{IMEFeff}} \times \text{Ncycles} \times (\%\text{DHWeff} \times \%\text{Natural Gas DHW} \times R_{\text{eff}}) + 
\]

\[22 \text{ Default assumption for unknown is based on percentage of homes with electric dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.}

\[23 \text{ Based on a weighted average of 295 clothes washer cycles per year assuming an average load runs for one hour (2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/)}

\[24 \text{ Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.} \]
3.7) * Therm_convert

Where:

Therm_convert = Conversion factor from kWh to Therm
                    = 0.03413

\( R_{eff} \) = Recovery efficiency factor
                    = 1.26

\%Natural Gas_DH\W = Percentage of DHW savings assumed to be Natural Gas

\begin{tabular}{|c|c|}
\hline
DHW fuel & \%Natural Gas_DH\W \\
\hline
Electric & 0\% \\
Natural Gas & 100\% \\
Unknown & 84\% \\
\hline
\end{tabular}

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

\begin{tabular}{|c|c|}
\hline
Dryer fuel & \%Gas_Dryer \\
\hline
Electric & 0\% \\
Natural Gas & 100\% \\
Unknown & 58\% \\
\hline
\end{tabular}

Other factors as defined above

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

\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
 & \multicolumn{4}{|c|}{\Delta\text{Therms}} & \multicolumn{2}{|c|}{\Delta\text{Water (gallons)}} & \\
 & Electric DHW & Gas DHW & Electric DHW & Gas DHW & Electric DHW & Gas DHW & Unknown DHW & Unknown DHW \\
& Electric Dryer & Gas Dryer & Unknown Dryer & Gas Dryer & Unknown Dryer & Gas Dryer & Electric Dryer & Gas Dryer \\
\hline
ENERGY STAR & 0.00 & 3.7 & 2.3 & 6.0 & 1.3 & 5.0 & 3.1 & 5.4 & 4.4 \\
ENERGY STAR Most Efficient & 0.00 & 6.6 & 3.1 & 9.8 & 1.8 & 8.4 & 5.6 & 8.7 & 7.4 \\
\hline
\end{tabular}

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\( \Delta\text{Water (gallons)} = \text{Capacity} \times (\text{IWF}_{\text{base}} - \text{IWF}_{\text{eff}}) \times \text{Ncycles} \)

Where

\( \text{IWF}_{\text{base}} = \text{Integrated Water Factor of baseline clothes washer} \)
\( = 5.92 \)

---

25 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.

26 Default assumption for unknown fuel is based on percentage of homes with gas dryer from EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

27 Ibid.

28 Weighted average IWF of Federal Standard rating for Front Loading and Top Loading units. Weighting is based upon the relative top v front loading percentage of available non-ENERGY STAR product in the CEC database.
IWFeff = Water Factor of efficient clothes washer
= Actual. If unknown assume average values provided below.

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

<table>
<thead>
<tr>
<th>Efficiency Level</th>
<th>IWF^29</th>
<th>∆Water (gallons per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Standard</td>
<td>5.92</td>
<td>0.0</td>
</tr>
<tr>
<td>ENERGY STAR</td>
<td>3.93</td>
<td>2024</td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</td>
<td>3.21</td>
<td>2760</td>
</tr>
</tbody>
</table>

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESCL-V04-160601**

**REVIEW DEADLINE: 1/1/2021**

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^29 IWFeff values are the weighted average of the new ENERGY STAR specifications. Weighting is based upon the relative top v front loading percentage of available ENERGY STAR and ENERGY STAR Most Efficient product in the CEC database. See “CW Analysis_01142016.xls” for the calculation.
5.1.3 ENERGY STAR Dehumidifier

**DESCRIPTION**

A dehumidifier meeting the minimum qualifying efficiency standard established by the current ENERGY STAR Version 3.0 (effective 10/1/2012) is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure, the new dehumidifier must meet the ENERGY STAR standards as defined below:

<table>
<thead>
<tr>
<th>Capacity (pints/day)</th>
<th>ENERGY STAR Criteria (L/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;75</td>
<td>≥1.85</td>
</tr>
<tr>
<td>75 to ≤185</td>
<td>≥2.80</td>
</tr>
</tbody>
</table>

Qualifying units shall be equipped with an adjustable humidistat control or shall require a remote humidistat control to operate.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline for this measure is defined as a new dehumidifier that meets the Federal Standard efficiency standards. The Federal Standard for Dehumidifiers as of October 2012 is defined below:

<table>
<thead>
<tr>
<th>Capacity (pints/day)</th>
<th>Federal Standard Criteria (L/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 35</td>
<td>≥1.35</td>
</tr>
<tr>
<td>&gt; 35 to ≤45</td>
<td>≥1.50</td>
</tr>
<tr>
<td>&gt; 45 to ≤54</td>
<td>≥1.60</td>
</tr>
<tr>
<td>&gt; 54 to ≤75</td>
<td>≥1.70</td>
</tr>
<tr>
<td>&gt; 75 to ≤185</td>
<td>≥2.50</td>
</tr>
</tbody>
</table>

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The assumed lifetime of the measure is 12 years\(^ {30} \).

**DEEMED MEASURE COST**

The assumed incremental capital cost for this measure is $60\(^ {31} \).

**LOADSHAPE**

Loadshape R12 - Residential - Dehumidifier

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\(^ {30} \) EPA Research, 2012; ENERGY STAR Dehumidifier Calculator

\(^ {31} \) Based on extrapolating available data from the Department of Energy's Life Cycle Cost analysis spreadsheet and weighting based on volume of units available:

See 'DOE life cycle cost_dehumidifier.xls' for calculation.
COINCIDENCE FACTOR

The coincidence factor is assumed to be 37%\(^{32}\).

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta \text{kWh} = \left(\frac{\text{Avg Capacity} \times 0.473}{24}\right) \times \text{Hours} \times \frac{1}{(L/\text{kWh}_\text{Base})} - \frac{1}{(L/\text{kWh}_\text{Eff})}
\]

Where:

- **Avg Capacity** = Average capacity of the unit (pints/day)
  = Actual, if unknown assume capacity in each capacity range as provided in table below, or if capacity range unknown assume average.
- **0.473** = Constant to convert Pints to Liters
- **24** = Constant to convert Liters/day to Liters/hour
- **Hours** = Run hours per year
  = 1632\(^{33}\)
- **L/kWh** = Liters of water per kWh consumed, as provided in tables above

Annual kWh results for each capacity class are presented below:

<table>
<thead>
<tr>
<th>Capacity Range (pints/day)</th>
<th>Capacity Used (pints/day)</th>
<th>Federal Standard Criteria (≥ L/kWh)</th>
<th>ENERGY STAR Criteria (≥ L/kWh)</th>
<th>Annual kWh</th>
<th>ENERGY STAR</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤25</td>
<td>20</td>
<td>1.35</td>
<td>1.85</td>
<td>477</td>
<td>348</td>
<td>129</td>
</tr>
<tr>
<td>&gt; 25 to ≤ 35</td>
<td>30</td>
<td>1.35</td>
<td>1.85</td>
<td>715</td>
<td>522</td>
<td>193</td>
</tr>
<tr>
<td>&gt; 35 to ≤ 45</td>
<td>40</td>
<td>1.5</td>
<td>1.85</td>
<td>858</td>
<td>695</td>
<td>162</td>
</tr>
<tr>
<td>&gt; 45 to ≤ 54</td>
<td>50</td>
<td>1.6</td>
<td>1.85</td>
<td>1005</td>
<td>869</td>
<td>136</td>
</tr>
<tr>
<td>&gt; 54 to ≤ 75</td>
<td>65</td>
<td>1.7</td>
<td>1.85</td>
<td>1230</td>
<td>1130</td>
<td>100</td>
</tr>
<tr>
<td>&gt; 75 to ≤ 185</td>
<td>130</td>
<td>2.5</td>
<td>2.8</td>
<td>1673</td>
<td>1493</td>
<td>179</td>
</tr>
<tr>
<td><strong>Average</strong>(^{34})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta \text{kW} = \frac{\Delta \text{kWh}}{\text{Hours}} \times \text{CF}
\]

\(^{32}\) 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%\(^{33}\)

\(^{33}\) ENERGY STAR Dehumidifier Calculator; 24 hour operation over 68 days of the year.

\(^{34}\) The relative weighting of each product class is based on number of units on the ENERGY STAR certified list. See “Dehumidifier Calcs.xls.”
Where:

- **Hours** = Annual operating hours
  - 1632 hours \(^{35}\)
- **CF** = Summer Peak Coincidence Factor for measure
  - 0.37 \(^{36}\)

Summer coincident peak demand results for each capacity class are presented below:

<table>
<thead>
<tr>
<th>Capacity (pints/day) Range</th>
<th>Annual Summer peak kW Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤25</td>
<td>0.029</td>
</tr>
<tr>
<td>&gt; 25 to ≤35</td>
<td>0.044</td>
</tr>
<tr>
<td>&gt; 35 to ≤45</td>
<td>0.037</td>
</tr>
<tr>
<td>&gt; 45 to ≤54</td>
<td>0.031</td>
</tr>
<tr>
<td>&gt; 54 to ≤75</td>
<td>0.023</td>
</tr>
<tr>
<td>&gt; 75 to ≤185</td>
<td>0.041</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.032</strong></td>
</tr>
</tbody>
</table>

**Natural Gas Savings**

N/A

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code:** RS-APL-ESDH-V03-160601

**Review Deadline:** 1/1/2019

\(^{35}\) Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator

\(^{36}\) 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%
5.1.4 ENERGY STAR Dishwasher

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.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient equipment is defined as a dishwasher meeting the efficiency specifications of ENERGY STAR. The Energy Star standard is presented in the table below:

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Maximum kWh/year</th>
<th>Maximum gallons/cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard (≥ 8 place settings + six serving pieces)</td>
<td>270</td>
<td>3.5</td>
</tr>
<tr>
<td>Standard with Connected Functionality37</td>
<td>283</td>
<td></td>
</tr>
<tr>
<td>Compact (&lt; 8 place settings + six serving pieces)</td>
<td>203</td>
<td>3.1</td>
</tr>
</tbody>
</table>

DEFINITION OF BASELINE EQUIPMENT

The Baseline reflects the minimum federal efficiency standards for dishwashers effective May 30, 2013, as presented in the table below38.

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Maximum kWh/year</th>
<th>Maximum gallons/cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>307</td>
<td>5.0</td>
</tr>
<tr>
<td>Compact</td>
<td>222</td>
<td>3.5</td>
</tr>
</tbody>
</table>

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the measure is 13 years39.

DEEMED MEASURE COST

The incremental cost for this measure is $5040.

---

37 The new ENERGY STAR specification “establishes optional connected criteria for dishwashers. ENERGY STAR certified dishwashers with connected functionality offer favorable attributes for demand response programs to consider, since their peak energy consumption is relatively high, driven by water heating. ENERGY STAR certified dishwashers with connected functionality will offer consumers new convenience and energy-saving features, such as alerts for cycle completion and/or recommended maintenance, as well as feedback on the energy use of the product”. See ‘ENERGY STAR Residential Dishwasher Final Version 6.0 Cover Memo.pdf’. Calculated as per Version 6.0 specification; “ENERGY STAR Residential Dishwasher Version 6.0 Final Program Requirements.pdf”. Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.


40 Estimate based on review of Energy Star stakeholder documents
LOADSHAPE

Loadshape R02 - Residential Dish Washer

COINCIDENCE FACTOR

The coincidence factor is assumed to be 2.6%.41

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh^{42} = (kWh_{\text{base}} - kWh_{\text{ESTAR}}) \times (\%kWh_{\text{op}} + (\%kWh_{\text{heat}} \times %\text{Electric}_\text{DHW})) \]

Where:

- \( kWh_{\text{BASE}} \) = Baseline kWh consumption per year
- \( kWh_{\text{ESTAR}} \) = ENERGY STAR kWh annual consumption
- \( %kWh_{\text{op}} \) = Percentage of dishwasher energy consumption used for unit operation
  - \( = 1 - 56\%^{43} \)
  - \( = 44\% \)
- \( %kWh_{\text{heat}} \) = Percentage of dishwasher energy consumption used for water heating
  - \( = 56\%^{44} \)
- \( %\text{Electric}_\text{DHW} \) = Percentage of DHW savings assumed to be electric

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Maximum kWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>307</td>
</tr>
<tr>
<td>Compact</td>
<td>222</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Maximum kWh/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>270</td>
</tr>
<tr>
<td>Standard with Connected Functionality</td>
<td>283</td>
</tr>
<tr>
<td>Compact</td>
<td>203</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Electric_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
</tbody>
</table>

41 Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
42 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.
43 ENERGY STAR Dishwasher Calculator
(\(\text{http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerDishwasher.xls}\))
44 Ibid.
### ENERGY STAR Dishwasher

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Electric_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>16(^{45})</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Electric DHW</td>
</tr>
<tr>
<td>ENERGY STAR Standard</td>
<td>37.0</td>
</tr>
<tr>
<td>ENERGY STAR Standard with Connected Functionality</td>
<td>24.0</td>
</tr>
<tr>
<td>ENERGY STAR Compact</td>
<td>19.0</td>
</tr>
</tbody>
</table>

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS\(^{46}\)

\[
\Delta kW = \Delta kWh/\text{Hours} \times CF
\]

Where:
- Hours = Annual operating hours\(^{47}\)
  - = 252 hours
- CF = Summer Peak Coincidence Factor
  - = 2.6\(^{48}\)

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>ΔkW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Electric DHW</td>
</tr>
<tr>
<td>ENERGY STAR Standard</td>
<td>0.0038</td>
</tr>
<tr>
<td>ENERGY STAR Standard with Connected Functionality</td>
<td>0.0025</td>
</tr>
<tr>
<td>ENERGY STAR Compact</td>
<td>0.0020</td>
</tr>
</tbody>
</table>

#### NATURAL GAS SAVINGS

\[
\Delta \text{Therm} = (\text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}}) \times \%\text{kWh}_{\text{heat}} \times \%\text{Natural Gas}_{\text{DHW}} \times R_{\text{eff}} \times 0.03413
\]

Where
- \%\text{kWh}_{\text{heat}} = \% of dishwasher energy used for water heating
  - = 56\%
- \%\text{Natural Gas}_{\text{DHW}} = Percentage of DHW savings assumed to be Natural Gas

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Natural Gas_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
</tbody>
</table>

\(^{45}\) Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

\(^{46}\) Note that the potential for demand response and additional peak savings from units with Connected Functionality have not been explored. This could be a potential addition in a future version.

\(^{47}\) Assuming one and a half hours per cycle and 168 cycles per year therefore 252 operating hours per year; 168 cycles per year is based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECs data; http://205.254.135.7/consumption/residential/data/2009/

\(^{48}\) End use data from Ameren representing the average DW load during peak hours/peak load.
**5.1.4 ENERGY STAR Dishwasher**

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Natural Gas_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>84%</td>
</tr>
</tbody>
</table>

- \( R_{\text{eff}} = \) Recovery efficiency factor
- \( = 1.26 \)
- \( 0.03413 = \) factor to convert from kWh to Therm

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>ΔTherms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Electric DHW</td>
</tr>
<tr>
<td>ENERGY STAR Standard</td>
<td>0.00</td>
</tr>
<tr>
<td>ENERGY STAR Standard with Connected Functionality</td>
<td>0.00</td>
</tr>
<tr>
<td>ENERGY STAR Compact</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[ \Delta \text{Water} = \text{Water}_{\text{Base}} - \text{Water}_{\text{EFF}} \]

Where

- \( \text{Water}_{\text{Base}} = \) water consumption of conventional unit
- \( \text{Water}_{\text{EFF}} = \) annual water consumption of efficient unit:

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Water_{\text{Base}} (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>840</td>
</tr>
<tr>
<td>Compact</td>
<td>588</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Water_{\text{EFF}} (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>588</td>
</tr>
<tr>
<td>Compact</td>
<td>521</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>ΔWater (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>252</td>
</tr>
<tr>
<td>Compact</td>
<td>67</td>
</tr>
</tbody>
</table>

49 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

50 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.

51 Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECS data; http://205.254.135.7/consumption/residential/data/2009/

52 Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECS data; http://205.254.135.7/consumption/residential/data/2009/

53 Assuming maximum allowed from specifications and 168 cycles per year based on a weighted average of dishwasher usage in Illinois derived from the 2009 RECS data; http://205.254.135.7/consumption/residential/data/2009/
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDI-V03-160601

REVIEW DEADLINE: 6/1/2018
5.1.5 ENERGY STAR Freezer

**DESCRIPTION**

A freezer meeting the efficiency specifications of ENERGY STAR is installed in place of a model meeting the federal standard (NAECA). Energy usage specifications are defined in the table below (note, AV is the freezer Adjusted Volume and is calculated as 1.73*Total Volume):

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Volume (cubic feet)</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Federal Baseline Maximum Energy Usage in kWh/year</td>
<td>ENERGY STAR Maximum Energy Usage in kWh/year</td>
</tr>
<tr>
<td>Upright Freezers with Manual Defrost</td>
<td>7.75 or greater</td>
<td>7.55*AV+258.3</td>
<td>6.795*AV+232.47</td>
</tr>
<tr>
<td>Upright Freezers with Automatic Defrost</td>
<td>7.75 or greater</td>
<td>12.43*AV+326.1</td>
<td>11.187*AV+293.49</td>
</tr>
<tr>
<td>Chest Freezers and all other Freezers except Compact Freezers</td>
<td>7.75 or greater</td>
<td>9.88*AV+143.7</td>
<td>8.892*AV+129.33</td>
</tr>
<tr>
<td>Compact Upright Freezers with Manual Defrost</td>
<td>&lt; 7.75 and 36 inches or less in height</td>
<td>9.78*AV+250.8</td>
<td>7.824*AV+200.64</td>
</tr>
<tr>
<td>Compact Upright Freezers with Automatic Defrost</td>
<td>&lt; 7.75 and 36 inches or less in height</td>
<td>11.40*AV+391</td>
<td>9.12*AV+312.8</td>
</tr>
<tr>
<td>Compact Chest Freezers</td>
<td>&lt; 7.75 and 36 inches or less in height</td>
<td>10.45*AV+152</td>
<td>8.36*AV+121.6</td>
</tr>
</tbody>
</table>

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is defined as a freezer meeting the efficiency specifications of ENERGY STAR, as defined below and calculated above:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Volume</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Size Freezer</td>
<td>7.75 cubic feet or greater</td>
<td>At least 10% more energy efficient than the minimum federal government standard (NAECA).</td>
</tr>
<tr>
<td>Compact Freezer</td>
<td>Less than 7.75 cubic feet and 36 inches or less in height</td>
<td>At least 20% more energy efficient than the minimum federal government standard (NAECA).</td>
</tr>
</tbody>
</table>

---


DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be a model that meets the federal minimum standard for energy efficiency. The standard varies depending on the size and configuration of the freezer (chest freezer or upright freezer, automatic or manual defrost) and is defined in the table above.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 11 years\(^{58}\).

DEEMED MEASURE COST

The incremental cost for this measure is $35\(^{59}\).

LOADSHAPE

Loadshape R04 - Residential Freezer

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 95\(^{60}\).

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS:

\[ \Delta \text{kWh} = \text{kWh}_{\text{Base}} - \text{kWh}_{\text{ESTAR}} \]

Where:

\[ \text{kWh}_{\text{Base}} = \text{Baseline kWh consumption per year as calculated in algorithm provided in table above.} \]

\[ \text{kWh}_{\text{ESTAR}} = \text{ENERGY STAR kWh consumption per year as calculated in algorithm provided in table above.} \]

For example for a 7.75 cubic foot Upright Freezers with Manual Defrost purchased after September 2014:

\[ \Delta \text{kWh} = (5.57 \times (7.75 \times 1.73) + 193.7) - (5.01 \times (7.75 \times 1.73) + 174.3) \]

\[ = 268.4 - 241.5 \]

\[ = 26.9 \text{ kWh} \]

If volume is unknown, use the following default values:

\(^{58}\) Energy Star Freezer Calculator; http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Freezer_Sav_Calc.xls?570a-f000


\(^{60}\) Based on eShapes Residential Freezer load data as provided by Ameren.
### ENERGY STAR Freezer

#### Product Category

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Volume Used</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kWh BASE</td>
<td>kWh ESTAR</td>
</tr>
<tr>
<td>Upright Freezers with Manual Defrost</td>
<td>27.9</td>
<td>469.1</td>
<td>422.2</td>
</tr>
<tr>
<td>Upright Freezers with Automatic Defrost</td>
<td>27.9</td>
<td>673.2</td>
<td>605.9</td>
</tr>
<tr>
<td>Chest Freezers and all other Freezers except Compact Freezers</td>
<td>27.9</td>
<td>419.6</td>
<td>377.6</td>
</tr>
<tr>
<td>Compact Upright Freezers with Manual Defrost</td>
<td>10.4</td>
<td>352.3</td>
<td>281.9</td>
</tr>
<tr>
<td>Compact Upright Freezers with Automatic Defrost</td>
<td>10.4</td>
<td>509.3</td>
<td>407.5</td>
</tr>
<tr>
<td>Compact Chest Freezers</td>
<td>10.4</td>
<td>260.5</td>
<td>208.4</td>
</tr>
</tbody>
</table>

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

∑ΔkW = ∆kWh/ Hours * CF

Where:

- ∆kWh = Gross customer annual kWh savings for the measure
- Hours = Full Load hours per year
  = 5890^{62}
- CF = Summer Peak Coincident Factor
  = 0.95^{63}

For example for a 7.75 cubic foot Upright Freezers with Manual Defrost:

$$\Delta kW = \frac{26.9}{5890} \times 0.95$$

$$= 0.0043 \text{ kW}$$

If volume is unknown, use the following default values:

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kW Savings</td>
<td>kW Savings</td>
</tr>
<tr>
<td>Upright Freezers with Manual Defrost</td>
<td>0.0076</td>
<td>0.0057</td>
</tr>
<tr>
<td>Upright Freezers with Automatic Defrost</td>
<td>0.0109</td>
<td>0.0076</td>
</tr>
<tr>
<td>Chest Freezers and all other Freezers except Compact Freezers</td>
<td>0.0068</td>
<td>0.0050</td>
</tr>
<tr>
<td>Compact Upright Freezers with Manual Defrost</td>
<td>0.0114</td>
<td>0.0075</td>
</tr>
</tbody>
</table>

^{61} Volume is based on ENERGY STAR Calculator assumption of 16.14 ft³ average volume, converted to Adjusted volume by multiplying by 1.73.

^{62} Calculated from eShapes Residential Freezer load data as provided by Ameren by dividing total annual load by the maximum kW in any one hour.

^{63} Based on eShapes Residential Freezer load data as provided by Ameren.
<table>
<thead>
<tr>
<th>Product Category</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kW Savings</td>
<td>kW Savings</td>
</tr>
<tr>
<td>Compact Upright Freezers with Automatic Defrost</td>
<td>0.0164</td>
<td>0.0103</td>
</tr>
<tr>
<td>Compact Chest Freezers</td>
<td>0.0084</td>
<td>0.0064</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESFR-V02-140601**

**REVIEW DEADLINE: 1/1/2021**
5.1.6 ENERGY STAR and CEE Tier 2 Refrigerator

**DESCRIPTION**

This measure relates to:

a) **Time of Sale**: the purchase and installation of a new refrigerator meeting either ENERGY STAR or CEE TIER 2 specifications.

b) **Early Replacement**: the early removal of an existing residential inefficient Refrigerator from service, prior to its natural end of life, and replacement with a new ENERGY STAR or CEE Tier 2 qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

Energy usage specifications are defined in the table below (note, Adjusted Volume is calculated as the fresh volume + (1.63 * Freezer Volume):

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Existing Unit</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on Refrigerator Recycling algorithm</td>
<td>Federal Baseline Maximum Energy Usage in kWh/year</td>
<td>ENERGY STAR Maximum Energy Usage in kWh/year</td>
<td>Federal Baseline Maximum Energy Usage in kWh/year</td>
</tr>
<tr>
<td>1. Refrigerators and Refrigerator-freezers with manual defrost</td>
<td>8.82*AV+248.4</td>
<td>7.056*AV+198.72</td>
<td>6.79AV + 193.6</td>
</tr>
<tr>
<td>2. Refrigerator-Freezer-partial automatic defrost</td>
<td>8.82*AV+248.4</td>
<td>7.056*AV+198.72</td>
<td>7.99AV + 225.0</td>
</tr>
<tr>
<td>Use Algorithm in 5.1.8 Refrigerator and Freezer Recycling measure to estimate existing unit consumption</td>
<td>9.80*AV+276</td>
<td>7.84*AV+220.8</td>
<td>8.07AV + 233.7</td>
</tr>
<tr>
<td>4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service</td>
<td>4.91*AV+507.5</td>
<td>3.928*AV+406</td>
<td>8.51AV + 297.8</td>
</tr>
<tr>
<td>5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer</td>
<td>4.60*AV+459</td>
<td>3.68*AV+367.2</td>
<td>8.85AV + 317.0</td>
</tr>
</tbody>
</table>

---

64 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
66 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
<table>
<thead>
<tr>
<th>Product Category</th>
<th>Existing Unit</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Based on Refrigerator Recycling algorithm</td>
<td>Federal Baseline Maximum Energy Usage in kWh/year</td>
<td>ENERGY STAR Maximum Energy Usage in kWh/year</td>
</tr>
<tr>
<td>without through-the-door ice service</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>through-the-door ice service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Refrigerator-Freezers—automatic defrost with top-mounted freezer with</td>
<td></td>
<td>10.20*AV+356</td>
<td>8.16*AV+284.8</td>
</tr>
<tr>
<td>through-the-door ice service</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Refrigerator-Freezers—automatic defrost with side-mounted freezer with</td>
<td></td>
<td>10.10*AV+406</td>
<td>8.08*AV+324.8</td>
</tr>
<tr>
<td>through-the-door ice service</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient equipment is defined as a refrigerator meeting the efficiency specifications of ENERGY STAR or CEE Tier 2 (defined as requiring >= 20% or >= 25% less energy consumption than an equivalent unit meeting federal standard requirements respectively). The ENERGY STAR standard varies according to the size and configuration of the unit, as shown in table above.

**DEFINITION OF BASELINE EQUIPMENT**

Time of Sale: baseline is a new refrigerator meeting the minimum federal efficiency standard for refrigerator efficiency. The current federal minimum standard varies according to the size and configuration of the unit, as shown in table above. Note also that this federal standard will be increased for units manufactured after September 1, 2014.

Early Replacement: the baseline is the existing refrigerator for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.
**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 12 years.\(^{68}\)

Remaining life of existing equipment is assumed to be 4 years\(^{69}\)

**DEEMED MEASURE COST**

Time of Sale: The incremental cost for this measure is assumed to be $40\(^{70}\) for an ENERGY STAR unit and $140\(^{71}\) for a CEE Tier 2 unit.

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $451 for ENERGY STAR unit and $551 for CEE Tier 2 unit\(^{72}\).

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $413\(^{73}\). This cost should be discounted to present value using the nominal societal discount rate.

**LOADSHAPE**

Loadshape R05 - Residential Refrigerator

**COINCIDENCE FACTOR**

A coincidence factor is not used to calculate peak demand savings for this measure, see below.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS:**

Time of Sale:  \[ \Delta \text{kWh} = UEC_{\text{BASE}} - UEC_{\text{EE}} \]

Early Replacement:

\[ \Delta \text{kWh for remaining life of existing unit (1st 4 years)} = UEC_{\text{EXIST}} - UEC_{\text{EE}} \]

\[ \Delta \text{kWh for remaining measure life (next 8 years)} = UEC_{\text{BASE}} - UEC_{\text{EE}} \]

Where:

\[ UEC_{\text{EXIST}} = \text{Annual Unit Energy Consumption of existing unit as calculated in algorithm from 5.1.8 Refrigerator and Freezer Recycling measure.} \]

\[ UEC_{\text{BASE}} = \text{Annual Unit Energy Consumption of baseline unit as calculated in algorithm provided in} \]

---


\(^{69}\) Standard assumption of one third of effective useful life.

\(^{70}\) From ENERGY STAR calculator linked above.


\(^{72}\) ENERGY STAR full cost is based upon IL PHA Efficient Living Program data on sample size of 910 replaced units finding average cost of $430 plus an average recycling/removal cost of $21. The CEE Tier 2 estimate uses the delta from the Time of Sale estimate.

\(^{73}\) Calculated using incremental cost from Time of Sale measure and applying inflation rate of 1.91%. 

---

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For CEE Tier 2, unit consumption is calculated as 25% lower than baseline.

If volume is unknown, use the following defaults, based on an assumed Adjusted Volume of 25.8\textsuperscript{74}:

Assumptions prior to standard changes on September 1\textsuperscript{st}, 2014:

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Existing Unit UEC\textsubscript{EXIST} 75</th>
<th>New Baseline UEC\textsubscript{BASE}</th>
<th>New Efficient UEC\textsubscript{EE}</th>
<th>Early Replacement (1\textsuperscript{st} 4 years) ΔkWh</th>
<th>Time of Sale and Early Replacement (last 8 years) ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Refrigerators and Refrigerator-freezers with manual defrost</td>
<td>1027.7</td>
<td>475.7</td>
<td>380.5</td>
<td>647.2</td>
<td>671.0</td>
</tr>
<tr>
<td>2. Refrigerator-Freezer--partial automatic defrost</td>
<td>1027.7</td>
<td>475.7</td>
<td>380.5</td>
<td>647.2</td>
<td>671.0</td>
</tr>
<tr>
<td>3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost</td>
<td>814.5</td>
<td>528.5</td>
<td>422.8</td>
<td>391.7</td>
<td>418.1</td>
</tr>
<tr>
<td>4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service</td>
<td>1241.0</td>
<td>634.0</td>
<td>507.2</td>
<td>733.7</td>
<td>765.4</td>
</tr>
<tr>
<td>5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service</td>
<td>814.5</td>
<td>577.5</td>
<td>462.0</td>
<td>352.5</td>
<td>381.4</td>
</tr>
<tr>
<td>6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service</td>
<td>814.5</td>
<td>618.8</td>
<td>495.1</td>
<td>319.5</td>
<td>350.4</td>
</tr>
<tr>
<td>7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service</td>
<td>1241.0</td>
<td>666.3</td>
<td>533.0</td>
<td>707.9</td>
<td>741.3</td>
</tr>
</tbody>
</table>

Assumptions after standard changes on September 1\textsuperscript{st}, 2014:

\textsuperscript{74} Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft\textsuperscript{3} fresh volume and 6.76 ft\textsuperscript{3} freezer volume.

\textsuperscript{75} Estimates of existing unit consumption are based on using the 5.1.8 Refrigerator and Freezer Recycling algorithm and the inputs described here: Age = 10 years, Pre-1990 = 0, Size = 21.5 ft\textsuperscript{3} (from ENERGY STAR calc and consistent with AV of 25.8), Single Door = 0, Side by side = 1 for classifications stating side by side, 0 for classifications stating top/bottom, and 0.5 for classifications that do not distinguish, Primary appliances = 1, unconditioned = 0, Part use factor = 0.
### Product Category

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Existing Unit UEC&lt;sub&gt;EXIST&lt;/sub&gt;</th>
<th>New Baseline UEC&lt;sub&gt;BASE&lt;/sub&gt;</th>
<th>New Efficient UEC&lt;sub&gt;CEE&lt;/sub&gt;</th>
<th>Early Replacement (1&lt;sup&gt;st&lt;/sup&gt; 4 years) ΔkWh</th>
<th>Time of Sale and Early Replacement (last 8 years) ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Refrigerators and Refrigerator-freezers with manual defrost</td>
<td>1027.7</td>
<td>368.6</td>
<td>331.6</td>
<td>276.4</td>
<td>696.1</td>
</tr>
<tr>
<td>2. Refrigerator-Freezer--partial automatic defrost</td>
<td>1027.7</td>
<td>430.9</td>
<td>387.8</td>
<td>323.2</td>
<td>640.0</td>
</tr>
<tr>
<td>3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost</td>
<td>814.5</td>
<td>441.7</td>
<td>397.4</td>
<td>331.2</td>
<td>417.2</td>
</tr>
<tr>
<td>4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service</td>
<td>1241.0</td>
<td>517.1</td>
<td>465.4</td>
<td>387.8</td>
<td>775.6</td>
</tr>
<tr>
<td>5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service</td>
<td>814.5</td>
<td>545.1</td>
<td>490.7</td>
<td>408.8</td>
<td>323.9</td>
</tr>
<tr>
<td>5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service</td>
<td>814.5</td>
<td>713.8</td>
<td>651.0</td>
<td>535.3</td>
<td>163.6</td>
</tr>
<tr>
<td>6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service</td>
<td>814.5</td>
<td>601.9</td>
<td>550.1</td>
<td>451.4</td>
<td>264.4</td>
</tr>
<tr>
<td>7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service</td>
<td>1241.0</td>
<td>652.9</td>
<td>596.1</td>
<td>489.6</td>
<td>644.9</td>
</tr>
</tbody>
</table>

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta kW = (\Delta kWh / 8766) \times TAF \times LSAF
\]

Where:

- \(TAF\) = Temperature Adjustment Factor

---

<sup>76</sup> Estimates of existing unit consumption are based on using the 5.1.8 Refrigerator and Freezer Recycling algorithm and the inputs described here: Age = 10 years, Pre-1990 = 0, Size = 21.5 ft³ (from ENERGY STAR calc and consistent with AV of 25.8), Single Door = 0, Side by side = 1 for classifications stating side by side, 0 for classifications stating top/bottom, and 0.5 for classifications that do not distinguish, Primary appliances = 1, unconditioned = 0, Part use factor = 0.
### Energy Savings

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Assumptions prior to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Early Replacement (1st 4 years)</td>
<td>Time of Sale and Early Replacement (last 8 years)</td>
</tr>
<tr>
<td></td>
<td>ENERGY STAR</td>
<td>CEE T2</td>
</tr>
<tr>
<td>1. Refrigerators and Refrigerator-freezers with manual defrost</td>
<td>0.098</td>
<td>0.101</td>
</tr>
<tr>
<td>2. Refrigerator-Freezer--partial automatic defrost</td>
<td>0.098</td>
<td>0.101</td>
</tr>
<tr>
<td>3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost</td>
<td>0.059</td>
<td>0.063</td>
</tr>
<tr>
<td>4. Refrigerator-Freezers--automatic defrost with side-mounted freezer without through-the-door ice service</td>
<td>0.111</td>
<td>0.115</td>
</tr>
<tr>
<td>5. Refrigerator-Freezers--automatic defrost with bottom-mounted freezer without through-the-door ice service</td>
<td>0.053</td>
<td>0.057</td>
</tr>
<tr>
<td>5A Refrigerator-freezer--automatic defrost with bottom-mounted freezer with through-the-door ice service</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>6. Refrigerator-Freezers--automatic defrost with top-mounted freezer with through-the-door ice service</td>
<td>0.048</td>
<td>0.053</td>
</tr>
<tr>
<td>7. Refrigerator-Freezers--automatic defrost with side-mounted freezer with through-the-door ice service</td>
<td>0.107</td>
<td>0.112</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**

N/A

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78 Daily load shape adjustment factor (average load in peak period /average daily load) 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 13 through 17)

---
WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: RS-APL-ESRE-V05-180101

REVIEW DEADLINE: 1/1/2021
5.1.7 ENERGY STAR Room Air Conditioner

DESCRIPTION

This measure relates to:

a) Time of Sale the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.0 which is effective October 26th, 2015), in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014.

<table>
<thead>
<tr>
<th>Product Type and Class (Btu/hr)</th>
<th>Federal Standard with louvered sides (CEER)</th>
<th>Federal Standard without louvered sides (CEER)</th>
<th>ENERGY STAR v4.0 with louvered sides (CEER)</th>
<th>ENERGY STAR v4.0 without louvered sides (CEER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without Reverse Cycle</td>
<td>&lt; 8,000</td>
<td>11.0</td>
<td>10.0</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>8,000 to 10,999</td>
<td>10.9</td>
<td>9.6</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>11,000 to 13,999</td>
<td>10.9</td>
<td>9.5</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>14,000 to 19,999</td>
<td>10.7</td>
<td>9.3</td>
<td>11.2</td>
</tr>
<tr>
<td></td>
<td>20,000 to 24,999</td>
<td>9.4</td>
<td>9.4</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td>&gt;=25,000</td>
<td>9.0</td>
<td>9.4</td>
<td>9.4</td>
</tr>
<tr>
<td>With Reverse Cycle</td>
<td>&lt;14,000</td>
<td>9.8</td>
<td>9.3</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>14,000 to 19,999</td>
<td>9.8</td>
<td>8.7</td>
<td>10.3</td>
</tr>
<tr>
<td></td>
<td>&gt;=20,000</td>
<td>9.3</td>
<td>8.7</td>
<td>9.7</td>
</tr>
<tr>
<td>Casement only</td>
<td></td>
<td>9.5</td>
<td></td>
<td>10.0</td>
</tr>
<tr>
<td>Casement-Slider</td>
<td></td>
<td>10.4</td>
<td></td>
<td>10.8</td>
</tr>
</tbody>
</table>

Side louvers extend from a room air conditioner model in order to position the unit in a window. A model without louvered sides is placed in a built-in wall sleeve and are commonly referred to as "through-the-wall" or "built-in" models.

Casement-only refers to a room air conditioner designed for mounting in a casement window of a specific size.

Casement-slider refers to a room air conditioner with an encased assembly designed for mounting in a sliding or casement window of a specific size.

Reverse cycle refers to the heating function found in certain room air conditioner models.

b) Early Replacement: the early removal of an existing residential inefficient Room AC unit from service, prior to its natural end of life, and replacement with a new ENERGY STAR qualifying unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR version 4.0 (effective October 26th, 2015) efficiency standards presented above.

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79 See DOE’s Appliance and Equipment Standards for Room AC; https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41
80 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
81 ENERGY STAR Version 4.0 Room Air Conditioners Program Requirements
DEFINITION OF BASELINE EQUIPMENT

Time of Sale: the baseline assumption is a new room air conditioning unit that meets the Federal Standard (effective June 1st, 2014)\(^{82}\) efficiency standards as presented above.

Early Replacement: the baseline is the existing Room AC for the assumed remaining useful life of the unit and the new baseline as defined above for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The measure life is assumed to be 12 years\(^ {83}\).

Remaining life of existing equipment is assumed to be 4 years\(^ {84}\).

DEEMED MEASURE COST

Time of Sale: The incremental cost for this measure is assumed to be $40 for a ENERGY STAR unit\(^ {85}\).

Early Replacement: The measure cost is the full cost of removing the existing unit and installing a new one. The actual program cost should be used. If unavailable assume $448 for ENERGY STAR unit\(^ {86}\).

The avoided replacement cost (after 4 years) of a baseline replacement unit is $432.\(^ {87}\) This cost should be discounted to present value using the nominal societal discount rate.

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 0.3\(^ {88}\).

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of Sale: \[ \Delta k\text{W} = \frac{(FLH_{\text{RoomAC}} \times \text{Btu/H} \times (1/C\text{EERbase} - 1/C\text{EERee}))}{1000} \]

Early Replacement:

\[ \Delta k\text{W} \text{ for remaining life of existing unit (1}^{st} 4 \text{ years) = (FLH}_{\text{RoomAC}} \times \text{Btu/H} \times (1/(\text{EERexist}/1.01) - } \]

\(^{82}\) See DOE’s Appliance and Equipment Standards for Room AC; https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41


\(^{84}\) Standard assumption of one third of effective useful life.

\(^{85}\) Incremental cost based on field study conducted by Efficiency Vermont.

\(^{86}\) Based on IL PHA Efficient Living Program Data for 810 replaced units showing $416 per unit plus $32 average recycling/removal cost.

\(^{87}\) Estimate based upon Time of Sale incremental costs and applying inflation rate of 1.91%.

\[ \Delta \text{kWh for remaining measure life (next 8 years)} = \frac{(\text{FLH}_{\text{RoomAC}} \times \text{Btu/H}) \times (1/\text{CEER}_{\text{base}} - 1/\text{CEER}_{\text{EE}})}{1000} \]

Where:

- **FLH\text{RoomAC}** = Full Load Hours of room air conditioning unit
- = dependent on location\(^{89}\):

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH\text{RoomAC}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>220</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>210</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>319</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>428</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>374</td>
</tr>
<tr>
<td>Weighted Average(^{90})</td>
<td>248</td>
</tr>
</tbody>
</table>

- **Btu/H** = Size of rebated unit
- = Actual. If unknown assume 8500 Btu/hr\(^{91}\)

- **EER\text{exist}** = Efficiency of existing unit
- = Actual. If unknown assume 7.7\(^{92}\)

- **1.01** = Factor to convert EER to CEER (CEER includes standby and off power consumption)\(^{93}\)

- **CEER\text{base}** = Combined Energy Efficiency Ratio of baseline unit
- = As provided in tables above

- **CEER\text{EE}** = Combined Energy Efficiency Ratio of ENERGY STAR unit
- = Actual. If unknown assume minimum qualifying standard as provided in tables above

\(^{89}\) Full load hours for room AC is significantly lower than for central AC. 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 for the same location (provided by AHRI: [http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)) is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the Energy Star calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\(^{90}\) Weighted based on number of residential occupied housing units in each zone.

\(^{91}\) Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008


\(^{93}\) Since the existing unit will be rated in EER, this factor is used to appropriately compare with the new CEER rating. Version 3.0 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See ‘ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements’.
**Time of Sale:**

For example for an 8,500 Btu/H capacity unit, with louvered sides, in an unknown location:

\[
\Delta \text{kWh}_{\text{CEE TIER 1}} = (248 \times 8500 \times (1/10.9 - 1/11.4)) / 1000 \\
= 8.5 \text{kWh}
\]

**Early Replacement:**

A 7.7EER, 9000Btu/h unit is removed from a home in Springfield and replaced with an ENERGY STAR unit with louvered sides:

\[
\Delta \text{kWh for remaining life of existing unit (1st 4 years)} = (319 \times 9000 \times (1/(7.7/1.01) - 1/11.4))/1000 \\
= 124.7 \text{kWh} \\
\Delta \text{kWh for remaining measure life (next 8 years)} = (319 \times 9000 \times (1/10.9 - 1/11.4))/1000 \\
= 11.6 \text{kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

- **Time of Sale:** \( \Delta kW = \text{Btu/H} \times ((1/(\text{CEERbase} \times 1.01) - 1/(\text{CEERee} \times 1.01))/1000) \times \text{CF} \)
- **Early Replacement:** \( \Delta kW = \text{Btu/H} \times ((1/\text{EERexist} - 1/(\text{CEERee} \times 1.01))/1000) \times \text{CF} \)

Where:

- \( \text{CF} = \text{Summer Peak Coincidence Factor for measure} \)
- \( \text{CF} = 0.3^{94} \)
- \( 1.01 = \text{Factor to convert CEER to EER (CEER includes standby and off power consumption)}^{95} \)

Other variable as defined above.

---

94 Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008
95 Since the new CEER rating includes standby and off power consumption, for peak calculations it is more appropriate to apply the EER rating, but it appears as though new units will only be rated with a CEER rating. Version 3.0 of the ENERGY STAR specification provided equivalent EER and CEER ratings and for the most popular size band the EER rating is approximately 1% higher than the CEER. See ‘ENERGY STAR Version 3.0 Room Air Conditioners Program Requirements’.
Time of Sale:
For example for an 8,500 Btu/H capacity unit, with louvered sides, for an unknown location:
\[ \Delta kW_{CEE TIER 1} = \frac{(8500 * (1/(10.9 * 1.01) - 1/(11.4*1.01)))) / 1000 * 0.3}{ } \]
\[ \Delta kW_{CEE TIER 1} = 0.010 \text{ kW} \]

Early Replacement:
A 7.7 EER, 9000Btu/h unit is removed from a home in Springfield and replaced with an ENERGY STAR unit with louvered sides:
\[ \Delta kW_{for remaining life of existing unit (1st 4 years)} = \frac{(9000 * (1/7.7 - 1/(11.4 * 1.01)))) / 1000 * 0.3}{ } \]
\[ \Delta kW_{for remaining life of existing unit (1st 4 years)} = 0.12 \text{ kW} \]
\[ \Delta kW_{for remaining measure life (next 8 years)} = \frac{(9000 * (1/(10.9 * 1.01) - 1/(11.4 * 1.01)))) / 1000 * 0.3}{ } \]
\[ \Delta kW_{for remaining measure life (next 8 years)} = 0.011 \text{ kW} \]

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-ESRA-V06-180101**

**REVIEW DEADLINE: 1/1/2021**
5.1.8 Refrigerator and Freezer Recycling

**DESCRIPTION**

This measure describes savings from the retirement and recycling of inefficient but operational refrigerators and freezers. Savings are provided based on a 2013 workpaper provided by Cadmus that used data from a 2012 ComEd metering study and metering data from a Michigan study, to develop a regression equation that uses key inputs describing the retired unit. The savings are equivalent to the Unit Energy Consumption of the retired unit and should be claimed for the assumed remaining useful life of that unit. A part use factor is applied to account for those secondary units that are not in use throughout the entire year. The reader should note that the regression algorithm is designed to provide an accurate portrayal of savings for the population as a whole and includes those parameters that have a significant effect on the consumption. The precision of savings for individual units will vary.

The Net to Gross factor applied to these units should incorporate adjustments that account for:

- Those participants who would have removed the unit from the grid anyway (e.g. customers replacing their refrigerator via a big box store and using the pick-up option, customers taking their unit to the landfill or recycling station);
- Those participants who decided, based on the incentive provided by the Appliance Recycling program alone, to replace their existing inefficient unit with a new unit. This segment of participants is expected to be very small and documentation of their intentions will be gathered via telephone surveys (i.e., primary data sources). For such customers, the consumption of the new unit should be subtracted from the retired unit consumption and savings claimed for the remaining life of the existing unit. Note that participants who were already planning to replace their unit, and the incentive just ensured that the retired unit was recycled and not placed on the secondary market, should not be included in this adjustment.

This measure was developed to be applicable to the following program types: ERET.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

N/A

**DEFINITION OF BASELINE EQUIPMENT**

The existing inefficient unit must be operational and have a capacity of between 10 and 30 cubic feet.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The estimated remaining useful life of the recycling units is 8 years. 96

**DEEMED MEASURE COST**

Measure cost includes the customer’s value placed on their lost amenity, any customer transaction costs, and the cost of pickup and recycling of the refrigerator/freezer and should be based on actual costs of running the program. The payment (bounty) a Program Administrator makes to the customer serves as a proxy for the value the customer places on their lost amenity and any customer transaction costs. If unknown assume $17097 per unit.

---

96 KEMA “Residential refrigerator recycling ninth year retention study”, 2004
97 The $170 default assumption is based on $120 cost of pickup and recycling per unit and $50 proxy for customer transaction costs and value customer places on their lost amenity. $120 is cost of pickup and recycling based on similar Efficiency Vermont program. $50 is bounty, based on Ameren and ComEd program offerings as of 7/27/15.
LOADSHAPE
Loadshape R05 - Residential Refrigerator

COINCIDENCE FACTOR
The coincidence factor is assumed to be 0.00012.

Algorithm

Calculation of Savings

Energy Savings

Refrigerators:

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

<table>
<thead>
<tr>
<th>Independent Variable Description</th>
<th>Estimate Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>83.324</td>
</tr>
<tr>
<td>Age (years)</td>
<td>3.678</td>
</tr>
<tr>
<td>Pre-1990 (=1 if manufactured pre-1990)</td>
<td>485.037</td>
</tr>
<tr>
<td>Size (cubic feet)</td>
<td>27.149</td>
</tr>
<tr>
<td>Dummy: Side-by-Side (= 1 if side-by-side)</td>
<td>406.779</td>
</tr>
<tr>
<td>Dummy: Primary Usage Type (in absence of the program) (= 1 if primary unit)</td>
<td>161.857</td>
</tr>
<tr>
<td>Interaction: Located in Unconditioned Space x CDD/365.25</td>
<td>15.366</td>
</tr>
<tr>
<td>Interaction: Located in Unconditioned Space x HDD/365.25</td>
<td>-11.067</td>
</tr>
</tbody>
</table>

\[ \Delta kWh = [83.32 + (Age \times 3.68) + (Pre-1990 \times 485.04) + (Size \times 27.15) + (Side-by-side \times 406.78) + (Proportion of Primary Appliances \times 161.86) + (CDD/365.25 \times \text{unconditioned} \times 15.37) + (HDD/365.25 \times \text{unconditioned} \times -11.07)] \times \text{Part Use Factor} \]

Where:

- **Age** = Age of retired unit
- **Pre-1990** = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)
- **Size** = Capacity (cubic feet) of retired unit
- **Side-by-side** = Side-by-side dummy (= 1 if side-by-side, else 0)
- **Primary Usage** = Primary Usage Type (in absence of the program) dummy (= 1 if Primary, else 0)
- **Interaction:** Located in Unconditioned Space x CDD/365.25

98 Based on the specified regression, a small number of units may have negative energy and demand consumption. These are a function of the unit size and age, and should comprise a very small fraction of the population. While on an individual basis this result is counterintuitive it is important that these negative results remain such that as a population the average savings is appropriate.

99 Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in July 30, 2014 memo from Cadmus: “Appliance Recycling Update no single door July 30 2014”.

IL TRM v6.0 Vol. 3_February 8th, 2017_FINAL Page 39 of 299
(=1 * CDD/365.25 if in unconditioned space)

\[ CDD = \text{Cooling Degree Days} \]

= Dependent on location\(^{100}\):

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>CDD 65</th>
<th>CDD/365.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>820</td>
<td>2.25</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>842</td>
<td>2.31</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,108</td>
<td>3.03</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,570</td>
<td>4.30</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,370</td>
<td>3.75</td>
</tr>
</tbody>
</table>

Interaction: Located in Unconditioned Space x HDD/365.25

(=1 * HDD/365.25 if in unconditioned space)

\[ HDD = \text{Heating Degree Days} \]

= Dependent on location\(^{101}\):

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>HDD 65</th>
<th>HDD/365.25</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>6,569</td>
<td>17.98</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>6,339</td>
<td>17.36</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>5,497</td>
<td>15.05</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>4,379</td>
<td>11.99</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>4,476</td>
<td>12.25</td>
</tr>
</tbody>
</table>

Part Use Factor = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used\(^{102}\). For illustration purposes, this example uses 0.93\(^{103}\).

For example, the program averages for AIC’s ARP in PY4 produce the following equation:

\[
\Delta kWh = (83.32 + (22.81 * 3.68) + (0.45 * 485.04) + (18.82 * 27.15) + (0.17 * 406.78) + (0.34 * 161.86) + (1.29 * 15.37) + (6.49 * -11.07)) \times 0.93
\]

\[
= 969 \times 0.93
\]

\[
= 900.9 \text{ kWh}
\]

Freezers:

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

\(^{100}\) National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

\(^{101}\) National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

\(^{102}\) For example, the part-use factor that shall be applied to the current program year \(t\) (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility’s service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

\(^{103}\) Most recent refrigerator part-use factor from Ameren Illinois PY5 evaluation.
coefficients:\(^{104}\):

<table>
<thead>
<tr>
<th>Independent Variable Description</th>
<th>Estimate Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>132.12</td>
</tr>
<tr>
<td>Age (years)</td>
<td>12.130</td>
</tr>
<tr>
<td>Pre-1990 (=1 if manufactured pre-1990)</td>
<td>156.181</td>
</tr>
<tr>
<td>Size (cubic feet)</td>
<td>31.839</td>
</tr>
<tr>
<td>Chest Freezer Configuration (=1 if chest freezer)</td>
<td>-19.709</td>
</tr>
<tr>
<td>Interaction: Located in Unconditioned Space x CDD/365.25</td>
<td>9.778</td>
</tr>
<tr>
<td>Interaction: Located in Unconditioned Space x HDD/365.25</td>
<td>-12.755</td>
</tr>
</tbody>
</table>

\[ \Delta kW = (132.12 + (\text{Age} \times 12.13) + (\text{Pre-1990} \times 156.18) + \text{Size} \times 31.84) + \text{Chest Freezer} \times -19.71 + (\text{CDDs} \times 9.78) + (\text{HDDs} \times -12.75)] \times \text{Part Use Factor} \]

Where:
- \( \text{Age} \) = Age of retired unit
- \( \text{Pre-1990} \) = Pre-1990 dummy (=1 if manufactured pre-1990, else 0)
- \( \text{Size} \) = Capacity (cubic feet) of retired unit
- \( \text{Chest Freezer} \) = Chest Freezer dummy (= 1 if chest freezer, else 0)
- \( \text{CDD} \) = Cooling Degree Days (see table above)
- \( \text{HDD} \) = Heating Degree Days (see table above)
- \( \text{Part Use Factor} \) = To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used\(^{105}\). For illustration purposes, the example uses 0.85.\(^{106}\)

The program averages for AIC’s ARP PY4 program are used as an example.

\[
\Delta kW = 977 \times 0.825 \\
= 905 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \text{kWh/8766} \times \text{CF} \]

\(^{104}\) Energy savings are based on an average 30-year TMY temperature of 51.1 degrees. Coefficients provided in January 31, 2013 memo from Cadmus: “Appliance Recycling Update”.

\(^{105}\) For example, the part-use factor that shall be applied to the current program year \( t \) (PYt) for savings verification purposes should be determined through the PYt-2 participant surveys conducted in the respective utility’s service territory, if available. If an evaluation was not performed in PYt-2 the latest available evaluation should be used.

\(^{106}\) Most recent freezer part-use factor from Ameren Illinois Company PY5 evaluation.
Where:

- kWh = Savings provided in algorithm above
- CF = Coincident factor defined as summer kW/average kW
  - = 1.081 for Refrigerators
  - = 1.028 for Freezers

For example, the program averages for AIC’s ARP in PY4 produce the following equation:

\[
\Delta kW = \frac{806}{8766} \times 1.081
\]

\[
= 0.099 \text{ kW}
\]

**Natural Gas Savings**

N/A

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code:** RS-APL-RFRC-V06-160601

**Review Deadline:** 1/1/2022

---

107 Cadmus memo, February 12, 2013; “Appliance Recycling Update”
5.1.9 Room Air Conditioner Recycling

DESCRIPTION

This measure describes the savings resulting from running a drop off service taking existing residential, inefficient Room Air Conditioner units from service, prior to their natural end of life. This measure assumes that though a percentage of these units will be replaced this is not captured in the savings algorithm since it is unlikely that the incentive made someone retire a unit that they weren’t already planning to retire. The savings therefore relate to the unit being taken off the grid as opposed to entering the secondary market. The Net to Gross factor applied to these units should incorporate adjustments that account for those participants who would have removed the unit from the grid anyway.

This measure was developed to be applicable to the following program types: ERET.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

N/A. This measure relates to the retiring of an existing inefficient unit.

DEFINITION OF BASELINE EQUIPMENT

The baseline condition is the existing inefficient room air conditioning unit.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed remaining useful life of the existing room air conditioning unit being retired is 4 years\(^{108}\).

DEEMED MEASURE COST

The actual implementation cost for recycling the existing unit should be used.

LOADSHAPE

Loadshape R08 - Residential Cooling

COINCIDENCE FACTOR

The coincidence factor for this measure is assumed to be 30\%\(^{109}\).

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta \text{kWh} = \left( \frac{(\text{FLH}_{\text{RoomAC}} \times \text{Btu/hr} \times (1/\text{EER}_{\text{exist}}))}{1000} \right)
\]

Where:

\(^{108}\) A third of assumed measure life for Room AC.

\(^{109}\) Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

FLH_{\text{RoomAC}} = \text{Full Load Hours of room air conditioning unit}
\text{dependent on location}^{110}:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>\text{FLH}_{\text{RoomAC}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>220</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>210</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>319</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>428</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>374</td>
</tr>
<tr>
<td>Weighted Average^{111}</td>
<td>248</td>
</tr>
</tbody>
</table>

Btu/H = \text{Size of retired unit}
\text{Actual. If unknown assume 8500 Btu/hr}^{112}

EER_{\text{exist}} = \text{Efficiency of existing unit}
= 7.7^{113}

For example for an 8500 Btu/h unit in Springfield:

\[ \Delta \text{kWh} = \left( \frac{319 \times 8500 \times (1/7.7)}{1000} \right) \]
\[ = 352 \text{ kWh} \]

\text{SUMMER COINCIDENT PEAK DEMAND SAVINGS}

\[ \Delta \text{kW} = \left( \frac{\text{Btu/hr} \times (1/\text{EER}_{\text{exist}})}{1000} \right) \times \text{CF} \]

Where:

\[ \text{CF} = \text{Summer Peak Coincidence Factor for measure} \]
\[ = 0.3^{114} \]

---

\(^{110}\) The average ratio of FLH for Room AC (provided 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](http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)) to FLH for Central Cooling for the same location (provided by AHRI: [http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)) is 31%. This ratio is applied to those IL cities that have FLH for Central Cooling provided in the Energy Star calculator. For other cities this is extrapolated using the FLH assumptions VEIC have developed for Central AC. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\(^{111}\) Weighted based on number of residential occupied housing units in each zone.

\(^{112}\) Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008


\(^{114}\) Consistent with coincidence factors found in:
For example an 8500 Btu/h unit:

\[
\Delta kW = \frac{8500 \times (1/7.7)}{1000} \times 0.3
\]

\[
= 0.33 \text{ kW}
\]

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-APL-RARC-V01-120601**

**REVIEW DEADLINE: 1/1/2019**
5.1.10 ENERGY STAR Clothes Dryer

**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.\(^\text{115}\) ENERGY STAR provides criteria for both gas and electric clothes dryers.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

Clothes dryer must meet the ENERGY STAR criteria, as required by the program.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a clothes dryer meeting the minimum federal requirements for units manufactured on or after January 1, 2015.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 14 years.\(^\text{116}\)

**DEEMED MEASURE COST**

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152.\(^\text{117}\)

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

The coincidence factor for this measure is 3.8%.\(^\text{118}\)

---


\(^{117}\) Based on the difference in installed cost for an efficient dryer ($716) and standard dryer ($564). 

\(^{118}\) Based on coincidence factor of 3.8% for clothes washers
Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh = (Load/CEF_{base} - Load/CEF_{eff}) \times Ncycles \times \%Electric \]

Where:

- **Load** = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

<table>
<thead>
<tr>
<th>Dryer Size</th>
<th>Load (lbs)(^{119})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>8.45</td>
</tr>
<tr>
<td>Compact</td>
<td>3</td>
</tr>
</tbody>
</table>

**CEF_{base}** = 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\(^{120}\). If product class unknown, assume electric, standard.

<table>
<thead>
<tr>
<th>Product Class</th>
<th>CEF (lbs/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vented Electric, Standard (≥ 4.4 ft(^3))</td>
<td>3.11</td>
</tr>
<tr>
<td>Vented Electric, Compact (120V) (&lt; 4.4 ft(^3))</td>
<td>3.01</td>
</tr>
<tr>
<td>Vented Electric, Compact (240V) (&lt;4.4 ft(^3))</td>
<td>2.73</td>
</tr>
<tr>
<td>Ventless Electric, Compact (240V) (&lt;4.4 ft(^3))</td>
<td>2.13</td>
</tr>
<tr>
<td>Vented Gas</td>
<td>2.84(^{121})</td>
</tr>
</tbody>
</table>

**CEF_{eff}** = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.\(^{122}\) If product class unknown, assume electric, standard.

<table>
<thead>
<tr>
<th>Product Class</th>
<th>CEF (lbs/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vented or Ventless Electric, Standard (≥ 4.4 ft(^3))</td>
<td>3.93</td>
</tr>
<tr>
<td>Vented or Ventless Electric, Compact (120V) (&lt; 4.4 ft(^3))</td>
<td>3.80</td>
</tr>
<tr>
<td>Vented Electric, Compact (240V) (&lt; 4.4 ft(^3))</td>
<td>3.45</td>
</tr>
<tr>
<td>Ventless Electric, Compact (240V) (&lt; 4.4 ft(^3))</td>
<td>2.68</td>
</tr>
<tr>
<td>Vented Gas</td>
<td>3.48(^{123})</td>
</tr>
</tbody>
</table>

**Ncycles** = Number of dryer cycles per year. Use actual data if available. If unknown, use 283 cycles per year.\(^{124}\)

\(^{119}\) Based on ENERGY STAR test procedures. [https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers](https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers)

\(^{120}\) ENERGY STAR Draft 2 Version 1.0 Clothes Dryers Data and Analysis

\(^{121}\) Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

\(^{122}\) ENERGY STAR Clothes Dryers Key Product Criteria. [https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers](https://www.energystar.gov/index.cfm?c=clothesdry.pr_crit_clothes_dryers)

\(^{123}\) Federal standards report CEF for gas clothes dryers in terms of lbs/kWh. To determine gas savings, this number is later converted to therms.

%Electric = The percent of overall savings coming from electricity
= 100% for electric dryers, 16% for gas dryers

**EXAMPLE**

Time of Sale: For example, a standard, vented, electric clothes dryer:

\[
\Delta kW = \left(\frac{8.45}{3.11} - \frac{8.45}{3.93}\right) \times 283 \times 100% \\
= 160 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \Delta kWh/\text{Hours} \times \text{CF}
\]

Where:
- \(\Delta kWh\) = Energy Savings as calculated above
- Hours = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 283 hours per year.
- CF = Summer Peak Coincidence Factor for measure
  = 3.8%\

**EXAMPLE**

Time of Sale: For example, a standard, vented, electric clothes dryer:

\[
\Delta kW = 160/283 \times 3.8% \\
= 0.0215 \text{ kW}
\]

**NATURAL GAS SAVINGS**

Natural gas savings only apply to ENERGY STAR vented gas clothes dryers.

\[
\Delta \text{Therm} = \left(\frac{\text{Load/EFbase}}{\text{Load/CEFeff}}\right) \times \text{Ncycles} \times \text{Therm}_{-\text{convert}} \times \%\text{Gas}
\]

Where:
- \(\text{Therm}_{-\text{convert}}\) = Conversion factor from kWh to Therm
  = 0.03413
- \%Gas = Percent of overall savings coming from gas
  = 0% for electric units and 84% for gas units

---

125 %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.

126 ENERGY STAR qualified dryers have a maximum test cycle time of 80 minutes. Assume one hour per dryer cycle.

127 Based on coincidence factor of 3.8% for clothes washers.

128 %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.
EXAMPLE

Time of Sale: For example, a standard, vented, gas clothes dryer:

\[
\Delta \text{Therm} = (8.45/2.84 - 8.45/3.48) \times 283 \times 0.03413 \times 0.84 \\
= 4.44 \text{ therms}
\]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-ESDR-V01-150601

REVIEW DEADLINE: 1/1/2021
5.1.11 ENERGY STAR Water Coolers

DESCRIPTION

Water coolers are a home appliance that offer consumers the ability to enjoy hot and/or cold water on demand. This measure is the characterization of the purchasing and use of an ENERGY STAR certified water cooler in place of a conventional water cooler.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The high efficiency equipment is an ENERGY STAR certified water cooler meeting the ENERGY STAR 2.0 efficiency criteria.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is a standard or conventional, non-ENERGY STAR certified water cooler.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The estimated useful life for a water cooler is 10 years\(^{129}\).

DEEMED MEASURE COST

The incremental cost for this measure is estimated at $17\(^{130}\).

LOADSHAPE

Loadshape C53: Flat

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 1.0.

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh = (kWh_{base} - kWh_{ee}) \times Days \]

Where:

\[ kWh_{base} = \text{Daily energy use (kWh/day) for baseline water cooler}^{131} \]

<table>
<thead>
<tr>
<th>Type of Water Cooler</th>
<th>kWh(_{base})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot and Cold Water – Storage</td>
<td>1.090</td>
</tr>
<tr>
<td>Hot and Cold Water – On Demand</td>
<td>0.330</td>
</tr>
</tbody>
</table>

\(^{129}\) Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

\(^{130}\) Ameren Missouri PY3 Evaluation Report.

\(^{131}\) Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.
### ENERGY STAR Water Coolers

<table>
<thead>
<tr>
<th>Type of Water Cooler</th>
<th>kWh&lt;sub&gt;base&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Water Only</td>
<td>0.290</td>
</tr>
</tbody>
</table>

kWh<sub>ee</sub> = Daily energy use (kWh/day) for ENERGY STAR water cooler<sup>132</sup>

<table>
<thead>
<tr>
<th>Type of Water Cooler</th>
<th>kWh&lt;sub&gt;ee&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot and Cold Water – Storage</td>
<td>0.747</td>
</tr>
<tr>
<td>Hot and Cold Water – On Demand</td>
<td>0.170</td>
</tr>
<tr>
<td>Cold Water Only</td>
<td>0.157</td>
</tr>
</tbody>
</table>

Days = Number of days per year that the water cooler is in use

Days = 365.25 days<sup>133</sup>

Energy Savings:

<table>
<thead>
<tr>
<th>Type of Water Cooler</th>
<th>ΔkWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot and Cold Water – Storage</td>
<td>125.4</td>
</tr>
<tr>
<td>Hot and Cold Water – On Demand</td>
<td>58.4</td>
</tr>
<tr>
<td>Cold Water Only</td>
<td>48.7</td>
</tr>
</tbody>
</table>

**DEMAND SAVINGS**

\[ ΔkW = \frac{ΔkWh}{\text{Hours}} \times \text{CF} \]

Where:

- **Hours** = Number of hours per year water cooler is in use
  - Hours = 8766 hours<sup>134</sup>
- **CF** = Summer Peak Coincidence Factor for measure
  - CF = 1.0

Demand Savings:

<table>
<thead>
<tr>
<th>Type of Water Cooler</th>
<th>ΔkW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot and Cold Water - Storage</td>
<td>0.0143</td>
</tr>
<tr>
<td>Hot and Cold Water – On Demand</td>
<td>0.0067</td>
</tr>
<tr>
<td>Cold Water Only</td>
<td>0.0056</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**

N/A

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

---

<sup>132</sup> Average kWh/day for from the ENERGY STAR efficient product database.

<sup>133</sup> Savings Calculator for ENERGY STAR Certified Water Coolers, last updated 2009.

<sup>134</sup> Assumed 365 days per year and 24 hours per day as utilized in daily energy consumption from ENERGY STAR Program Requirements Product Specification for Water Coolers Test Method.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-APL-WTCL-V01-180101

REVIEW DEADLINE: 1/1/2024
5.2 Consumer Electronics End Use

5.2.1 Advanced Power Strip – Tier 1

DESCRIPTION

This measure relates to Advanced Power Strips – Tier 1 which are multi-plug surge protector power strips with the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced. Uncontrolled outlets are also provided that are not affected by the control device and so are always providing power to any device plugged into it. This measure characterization provides savings for a 5-plug strip and a 7-plug strip.

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient case is the use of a 5 or 7-plug advanced power strip.

DEFINITION OF BASELINE EQUIPMENT

For time of sale or new construction applications, the assumed baseline is a standard power strip that does not control connected loads.

For direct install and kits, the baseline is the existing equipment utilized in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of the advanced power strip is 7 years\(^\text{135}\).

DEEMED MEASURE COST

For time of sale or new construction the incremental cost of an advanced Tier 1 power strip over a standard power strip with surge protection is assumed to be $10\(^\text{136}\).

For direct install the actual full install cost (including labor) and for kits the full equipment cost should be used.

LOADSHAPE

Loadshape R13 - Residential Standby Losses – Entertainment

Loadshape R14 - Residential Standby Losses - Home Office

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 80\(^\text{137}\).

\(^{135}\) This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

\(^{136}\) Price survey performed by Illume Advising LLC for IL TRM workpaper, see “Current Surge Protector Costs and Comparison 7-2016” spreadsheet.

\(^{137}\) Efficiency Vermont 2016 TRM coincidence factor for advanced power strip measure – in the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta \text{kWh} = \text{kWh} \times \text{ISR}
\]

Where:

\[
\text{kWh} = \text{Assumed annual kWh savings per unit}
\]

\[
= 56.5 \text{ kWh for 5-plug units or 103 kWh for 7-plug units}^{138}
\]

\[
\text{ISR} = \text{In Service Rate, dependent on delivery mechanism}
\]

Using assumptions above:

<table>
<thead>
<tr>
<th># Plugs</th>
<th>Delivery Mechanism</th>
<th>( \Delta \text{kWh} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-plug</td>
<td>Energy Efficiency Kit</td>
<td>39.0</td>
</tr>
<tr>
<td></td>
<td>All other delivery mechanisms</td>
<td>56.5</td>
</tr>
<tr>
<td>7-plug</td>
<td>Energy Efficiency Kit</td>
<td>71.1</td>
</tr>
<tr>
<td></td>
<td>All other delivery mechanisms</td>
<td>103.0</td>
</tr>
<tr>
<td>Unknown</td>
<td>Energy Efficiency Kit</td>
<td>55.0</td>
</tr>
<tr>
<td></td>
<td>All other delivery mechanisms</td>
<td>80.0</td>
</tr>
</tbody>
</table>

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta \text{kW} = \Delta \text{kWh} / \text{Hours} \times \text{CF}
\]

Where:

\[
\text{Hours} = \text{Annual number of hours during which the controlled standby loads are turned off by the Tier 1 Advanced power Strip.}
\]

\[
= 7,129^{141}
\]

---

138 NYERDA Measure Characterization for Advanced Power Strips. Study based on review of: Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.

“Smart strip” in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC.

139 Average of Ameren Missouri, Potomac Edison, and PPL Electric ISR for smart strips in kits.


“Smart strip” in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC.

140 Calculated as average of 5 and 7 plug savings assumptions.

141 Average of hours for controlled TV and computer from; NYERDA Measure Characterization for Advanced Power Strips
CF = Summer Peak Coincidence Factor for measure
    = 0.8

<table>
<thead>
<tr>
<th># Plugs</th>
<th>Delivery Mechanism</th>
<th>ΔkW</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-plug</td>
<td>Energy Efficiency Kit</td>
<td>0.0044</td>
</tr>
<tr>
<td></td>
<td>All other delivery mechanisms</td>
<td>0.0063</td>
</tr>
<tr>
<td>7-plug</td>
<td>Energy Efficiency Kit</td>
<td>0.0080</td>
</tr>
<tr>
<td></td>
<td>All other delivery mechanisms</td>
<td>0.0116</td>
</tr>
<tr>
<td>Unknown</td>
<td>Energy Efficiency Kit</td>
<td>0.0062</td>
</tr>
<tr>
<td></td>
<td>All other delivery mechanisms</td>
<td>0.0090</td>
</tr>
</tbody>
</table>

**NATURAL GAS SAVINGS**
N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**
N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**
N/A

**MEASURE CODE: RS-CEL-SSTR-V03-180101**

**REVIEW DEADLINE: 1/1/2021**

---

142 Efficiency Vermont 2016 TRM coincidence factor for advanced power strip measure—in the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.

143 Calculated as average of 5 and 7 plug savings assumptions.
5.2.2 Tier 2 Advanced Power Strips (APS) – Residential Audio Visual

**DESCRIPTION**

This measure relates to the installation of a Tier 2 Advanced Power Strip / surge protector for household audio visual environments (Tier 2 AV APS). Tier 2 AV APS are multi-plug power strips that remove power from audio visual equipment through intelligent control and monitoring strategies.

By utilizing advanced control strategies such as a countdown timer, external sensors (e.g. of infra-red remote usage and/or occupancy sensors, true RMS (Root Mean Square) power sensing; both active power loads and standby power loads of controlled devices are managed by Tier 2 AV APS devices\(^\text{144}\). Monitoring and controlling both active and standby power loads of controlled devices will reduce the overall load of a centralized group of electrical equipment (i.e. the home entertainment center). This more intelligent sensing and control process has been demonstrated to deliver increased energy savings and demand reduction compared with ‘Tier 1 Advanced Power Strips’.

The Tier 2 APS market is a relatively new and developing one. With several new Tier 2 APS products coming to market, it is important that energy savings are clearly demonstrated through independent field trials. The IL Technical Advisory Committee have developed a protocol whereby product manufacturers must submit independent field trial evidence of the Energy Reduction Percentage of their particular product either to the TRM Administrator for consideration during the TRM update process (August – December), or engage with a Program Administrator’s independent evaluation team to review at other times. The product will be assigned a Product Class (A-H) corresponding to the proven savings and all products in a class will claim consistent savings. The IL TRM Administrator will maintain a list of eligible product and class on the IL TRM Sharepoint site. If a mid-year review has taken place, supporting information should be posted on the Sharepoint site such that other program administrators can review.

Due to the inherent variance day to day and week to week for hours of use of AV systems, it is critical that field trial studies effectively address the variability in usage patterns. There is significant discussion in the EM&V and academic domain on the optimal methodology for controlling for these factors and in submitting evidence of energy savings, it is critical that it is demonstrated that these issues are adequately addressed.

This measure was developed to be applicable to the following program types: DI. If applied to other program delivery types, the installation characteristics including the number of AV devices under control and an appropriate in service rate should be verified through evaluation.

Current evaluation is limited to Direct Install applications. Through a Direct Install program it can be assured that the APS is appropriately set up and the customer is knowledgeable about its function and benefit. It is encouraged that additional implementation strategies are evaluated to provide an indication of whether the units are appropriately set up, used with AV equipment and that the customer is knowledgeable about its function and benefit. This will then facilitate a basis for broadening out the deployment methods of the APS technology category beyond Direct Install.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient case is the use of a Tier 2 AV APS in a residential AV (home entertainment) environment that includes control of at least 2 AV devices with one being the television\(^\text{145}\).

Only Tier 2 AV APS products that have independent demonstrated energy savings via field trials are eligible.

The minimum product specifications for Tier 2 AV APS are:

---

\(^{144}\) Tier 2 AV APS identify when people are not engaged with their AV equipment and then remove power, for example a TV and its peripheral devices that are unintentionally left on when a person leaves the house or for instance where someone falls asleep while watching television.

\(^{145}\) Given this requirement, an AV environment consisting of a television and DVD player or a TV and home theater would be eligible for a Tier 2 AV APS installation.
Safety & longevity

- Third party tested to all applicable UL Standards.
- Contains a resettable circuit breaker
- Incorporates power switching electromechanical relays rated for 100,000 switching cycles at full 15 amp load (equivalent to more than 10 years of use).

Energy efficiency functionality

- Calculates real power as the time average of the instantaneous power, where instantaneous power is the product of instantaneous voltage and current.
- Delivers a warning when the countdown timer begins before an active power down event and maintains the warning until countdown is concluded or reset by use of the remote or other specified signal
- Uses an automatically adjustable power switching threshold.

DEFINITION OF BASELINE EQUIPMENT

The assumed baseline equipment is the existing equipment being used in the home (e.g. a standard power strip or wall socket) that does not control loads of connected AV equipment.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The default deemed lifetime value for Tier 2 AV APS is assumed to be 7 years\(^\text{146}\).

DEEMED MEASURE COST

Direct Installation: The actual installed cost (including labor) of the new Tier 2 AV APS equipment should be used.

LOADSHAPE

Loadshape R13 - Residential Standby Losses – Entertainment

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 80\(^\%\)\(^\text{147}\).

Algorithm

CALCULATION OF ENERGY SAVINGS

\[
\Delta \text{kWh} = \text{ERP} \times \text{BaselineEnergy}_{AV} \times \text{ISR}
\]

Where:

\(^\text{146}\) There is little evaluation to base a lifetime estimate upon. Based on review of assumptions from other jurisdictions and the relative treatment of In Service Rates and persistence, an estimate of 7 years was agreed by the Technical Advisory Committee, but further evaluation is recommended.

\(^\text{147}\) In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes.
ERP = Energy Reduction Percentage of qualifying Tier2 AV APS product range as provided below. See reference documents for Product Classification memo.

BaselineEnergy$_{AV}$ = 432 kWh$^{148}$

<table>
<thead>
<tr>
<th>Product Class</th>
<th>Field trial ERP range</th>
<th>ERP used</th>
<th>BaselineEnergy$_{AV}$ (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>55 – 60%</td>
<td>55%</td>
<td>238</td>
</tr>
<tr>
<td>B</td>
<td>50 – 54%</td>
<td>50%</td>
<td>216</td>
</tr>
<tr>
<td>C</td>
<td>45 – 49%</td>
<td>45%</td>
<td>194</td>
</tr>
<tr>
<td>D</td>
<td>40 – 44%</td>
<td>40%</td>
<td>173</td>
</tr>
<tr>
<td>E</td>
<td>35 – 39%</td>
<td>35%</td>
<td>151</td>
</tr>
<tr>
<td>F</td>
<td>30 – 34%</td>
<td>30%</td>
<td>130</td>
</tr>
<tr>
<td>G</td>
<td>25 – 29%</td>
<td>25%</td>
<td>108</td>
</tr>
<tr>
<td>H</td>
<td>20 – 24%</td>
<td>20%</td>
<td>86</td>
</tr>
</tbody>
</table>

ISR = In Service Rate. See reference documents for Product Classification memo.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh / \text{Hours} \times \text{CF} \]

Where:

- \( \Delta kWh \) = Energy savings as calculated above
- \( \text{Hours} \) = Annual number of hours during which the APS provides savings.
- \( \text{CF} = 4,380 \) $^{149}$
- \( \text{CF} = 0.8 \) $^{150}$

**NATURAL GAS SAVINGS**

N/A$^{151}$

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

$^{148}$ AESC, Inc, “Energy Savings of Tier 2 Advanced Power Strips in Residential AC Systems”, p28. Note that this load represents the average controlled AV devices only and will likely be lower than total AC usage.

$^{149}$ This is estimate based on assumption that approximately half of savings are during active hours (supported by AESC study) (assumed to be 5.3 hrs/day, 1936 per year (NYSERDA 2011. “Advanced Power Strip Research Report”)) and half during standby hours (8760-1936 = 6824 hours). The weighted average is 4380.

$^{150}$ In the absence of empirical evaluation data, this was based on assumptions of the typical run pattern for televisions and computers in homes. This appears to be supported by the Average Weekday AV Demand Profile and Reduction charts in the AESC study (p33-34). These show that the average demand reduction is relatively flat.

$^{151}$ Interactive effects of Tier 2 APS on space conditioning loads has not yet been adequately studied.
MEASURE CODE: RS-CEL-APS2-V02-180101

REVIEW DEADLINE: 1/1/2019
5.3 HVAC End Use
5.3.1 Air Source Heat Pump

DESCRIPTION

A heat pump provides heating or cooling by moving heat between indoor and outdoor air. This measure characterizes:

a) Time of Sale:

a. The installation of a new residential sized (<= 65,000 Btu/hr) air source heat pump that is more efficient than required by federal standards. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

The early removal of functioning electric heating and cooling (SEER 10 or under if present) systems from service, prior to its natural end of life, and replacement with a new high efficiency air source heat pump unit.

Early Replacement determination will be based on meeting the following conditions:

- The existing unit is operational when replaced, or
- The existing unit requires minor repairs (<$276 per ton)
- All other conditions will be considered Time of Sale.

The Baseline SEER of the existing unit replaced:

- If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 14.
- If the SEER of the existing unit is unknown, use assumptions in variable list below (SEER_exist and HSPF_exist).
- If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown.

<table>
<thead>
<tr>
<th>Deemed Early Replacement Rates For ASHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Replacement Rate for ASHP participants</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

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

152 The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

153 Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for ASHP installations since ASHP specific data is not available. Report presented to Nicor Gas Company February 27, 2014, available at http://www.ilsag.info/evaluation-documents.html.
DEFINITION OF EFFICIENT EQUIPMENT

A new residential sized (<= 65,000 Btu/hr) air source heat pump with specifications to be determined by program.

DEFINITION OF BASELINE EQUIPMENT

A new residential sized (<= 65,000 Btu/hr) air source heat pump meeting federal standards.

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level as of January 1st 2015; 14 SEER and 8.2 HSPF.

The baseline 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years.\textsuperscript{154}

Remaining life of existing ASHP/CAC equipment is assumed to be 6 years\textsuperscript{155} and 18 years for electric resistance.

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on the efficiency of the new unit\textsuperscript{156}.

<table>
<thead>
<tr>
<th>Efficiency (SEER)</th>
<th>Incremental Cost ($/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.5</td>
<td>$123</td>
</tr>
<tr>
<td>15</td>
<td>$303</td>
</tr>
<tr>
<td>16</td>
<td>$438</td>
</tr>
<tr>
<td>17</td>
<td>$724</td>
</tr>
<tr>
<td>18</td>
<td>$724</td>
</tr>
</tbody>
</table>

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume the following (note these costs are per ton of unit capacity)\textsuperscript{157}:

<table>
<thead>
<tr>
<th>Efficiency (SEER)</th>
<th>Full Retrofit Cost (including labor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.5</td>
<td>$1,381 / ton + $123</td>
</tr>
<tr>
<td>15</td>
<td>$1,381 / ton + $303</td>
</tr>
<tr>
<td>16</td>
<td>$1,381 / ton + $438</td>
</tr>
<tr>
<td>17</td>
<td>$1,381 / ton + $724</td>
</tr>
<tr>
<td>18</td>
<td>$1,381 / ton + $724</td>
</tr>
</tbody>
</table>

Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $1,518 per ton of capacity\textsuperscript{158}. This cost should be discounted to present value using the nominal societal discount rate.


\textsuperscript{155} Assumed to be one third of effective useful life

\textsuperscript{156} Based on incremental cost results from Cadmus “HVAC Program: Incremental Cost Analysis Update”, December 19, 2016.

\textsuperscript{157} Baseline cost per ton derived from DEER 2008 Database Technology and Measure Cost Data (\url{www.deeresources.com}). See ‘ASHP_Revised DEER Measure Cost Summary.xls’ for calculation. Efficiency cost increment consistent with Cadmus study results.

\textsuperscript{158} Ibid. $1381 per ton inflated using rate of 1.91%.
LOADSHAPE

Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\( \text{CF}_{\text{SSP, SF}} = \text{Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during } \text{utility peak hour}\) = 72% \)\(^{159}\)

\( \text{CF}_{\text{PJM, SF}} = \text{PJM Summer Peak Coincidence Factor for Heat Pumps in single-family homes (average during PJM peak period)} = 46.6\% \)\(^{160}\)

\( \text{CF}_{\text{SSP, MF}} = \text{Summer System Peak Coincidence Factor for Heat Pumps in multi-family homes (during } \text{system peak hour}\) = 67\% \)\(^{161}\)

\( \text{CF}_{\text{PJM, MF}} = \text{PJM Summer Peak Coincidence Factor for Heat Pumps in multi-family homes (average during peak period)} = 28.5\% \)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

\[ \Delta \text{kWh} = \left( \left( \text{FLH} \_ \text{cooling} \times \text{Capacity} \_ \text{cooling} \times \left( \frac{1}{\text{SEER} \_ \text{base}} - \frac{1}{\text{SEER} \_ \text{ee}} \right) \right) / 1000 \right) + \left( \left( \text{FLH} \_ \text{heat} \times \text{Capacity} \_ \text{heating} \times \left( \frac{1}{\text{HSPF} \_ \text{base}} - \frac{1}{\text{HSPF} \_ \text{ee}} \right) \right) / 1000 \right) \]

Early replacement\(^{162}\):

\[ \Delta \text{kWH for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):} = \left( \left( \text{FLH} \_ \text{cooling} \times \text{Capacity} \_ \text{cooling} \times \left( \frac{1}{\text{SEER} \_ \text{exist}} - \frac{1}{\text{SEER} \_ \text{ee}} \right) \right) / 1000 \right) + \left( \left( \text{FLH} \_ \text{heat} \times \text{Capacity} \_ \text{heating} \times \left( \frac{1}{\text{HSPF} \_ \text{base}} - \frac{1}{\text{HSPF} \_ \text{ee}} \right) \right) / 1000 \right) \]

\(^{159}\) Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.  
\(^{160}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.  
\(^{161}\) Multifamily coincidence factors both from; All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015  
\(^{162}\) 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).
\[ \text{Capacity}_{\text{heating}} \times \left( \frac{1}{\text{HSPF}_{\text{exist}} - \frac{1}{\text{HSPF}_{\text{ee}}}} \right) / 1000 \]

\[ \Delta k\text{W} \text{H for remaining measure life (next 12 years if replacing an ASHP):} \]

\[ = \left( \frac{\text{FLH}_{\text{cooling}} \times \text{Capacity}_{\text{cooling}} \times \left(1/\text{SEER}_{\text{base}} - \frac{1}{\text{SEER}_{\text{ee}}}ight)}{1000} \right) + \left( \frac{\text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times \left(1/\text{HSPF}_{\text{base}} - \frac{1}{\text{HSPF}_{\text{ee}}}ight)}{1000} \right) \]

Where:

\[ \text{FLH}_{\text{cooling}} = \text{Full load hours of air conditioning} \]

\[ = \text{dependent on location:} \]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>\text{FLH}_{\text{cooling}} (single family) \textsuperscript{163}</th>
<th>\text{FLH}_{\text{cooling}} (general multi family) \textsuperscript{164}</th>
<th>\text{FLH}_{\text{cooling}} (weatherized multi family) \textsuperscript{165}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
<td>299</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
<td>324</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
<td>425</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
<td>603</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
<td>526</td>
</tr>
<tr>
<td>Weighted Average\textsuperscript{166}</td>
<td>629</td>
<td>564</td>
<td>362</td>
</tr>
</tbody>
</table>

\[ \text{Capacity}_{\text{cooling}} = \text{Cooling Capacity of Air Source Heat Pump (Btu/hr)} \]

\[ = \text{Actual (1 ton = 12,000 Btu/hr)} \]

\[ \text{SEER}_{\text{exist}} = \text{Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)} \]

\[ = \text{Use actual SEER rating where it is possible to measure or reasonably estimate.} \]

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>\text{SEER}_{\text{exist}} \textsuperscript{167}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>9.12</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.60</td>
</tr>
<tr>
<td>No central cooling\textsuperscript{168}</td>
<td>Make ‘1/\text{SEER}_{\text{exist}}’ = 0</td>
</tr>
</tbody>
</table>

\[ \text{SEER}_{\text{base}} = \text{Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)} \]

\[ = 14 \textsuperscript{169} \]

\[ \text{SEER}_{\text{ee}} = \text{Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/kWh)} \]

\textsuperscript{163} Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{164} Ibid.

\textsuperscript{165} All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015. The multifamily units within this study had undergone significant shell improvements (air sealing and insulation) and therefore this set of assumptions is only appropriate for units that have recently participated in a weatherization or other shell program. Note that the FLH\text{cool} where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

\textsuperscript{166} Weighted based on number of occupied residential housing units in each zone.

\textsuperscript{167} Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

\textsuperscript{168} 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.

= Actual
FLH_heat = Full load hours of heating
= Dependent on location and home type:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_heat (single family and general multi family)</th>
<th>FLH heat (weatherized multi family)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,969</td>
<td>748</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,840</td>
<td>699</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,754</td>
<td>667</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,266</td>
<td>481</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,288</td>
<td>489</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>1,821</td>
<td>692</td>
</tr>
</tbody>
</table>

Capacity_heating = Heating Capacity of Air Source Heat Pump (Btu/hr)
= Actual (1 ton = 12,000Btu/hr)

HSPF_exist = Heating System Performance Factor of existing heating system (kBtu/kWh)
= Use actual HSPF rating where it is possible to measure or reasonably estimate. If not available use:

<table>
<thead>
<tr>
<th>Existing Heating System</th>
<th>HSPF_exist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>5.44</td>
</tr>
<tr>
<td>Electric Resistance</td>
<td>3.41</td>
</tr>
</tbody>
</table>

HSPF_base = Heating System Performance Factor of baseline Air Source Heat Pump (kBtu/kWh)
= 8.2

HSPF_ee = Heating System Performance Factor of efficient Air Source Heat Pump (kBtu/kWh)

---

170 Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the Energy Star Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider Energy Star estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from http://www.icc.illinois.gov/ags/consumereducation.aspx) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the Energy Star data (1994 hours) to scale down the Energy Star estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

171 *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015.

172 Weighted based on number of occupied residential housing units in each zone.

173 HSPF ratings for Heat Pumps account for the seasonal average efficiency of the units and are based on testing within zone 4 which encompasses most of Illinois. Furthermore, a recent Cadmus/Opinion Dynamics metering study, “Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)”, found no significant variance between metered performance and that presented in the TRM.

174 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 average nameplate SEER rating of all Early Replacement qualifying equipment in Ameren PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF.

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

SUMMER COINCIDENT PEAK DEMAND SAVINGS

Time of Sale:
For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in a single family home in Marion:

$$\Delta \text{kWh} = \left( \frac{903 \times 36,000 \times (1/14 - 1/15)}{1000} \right) + \left( \frac{1,288 \times 36,000 \times (1/8.2 - 1/9)}{1000} \right)$$

$$= 657 \text{kWh}$$

Early Replacement:
For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump replaces an existing working Air Source Heat Pump with unknown efficiency ratings in a single family home in Marion:

$$\Delta \text{kWh for remaining life of existing unit (1st 6 years):}$$

$$= \left( \frac{903 \times 36,000 \times (1/9.12 - 1/15)}{1000} \right) + \left( \frac{1,288 \times 36,000 \times (1/5.44 - 1/9)}{1000} \right)$$

$$= 4769 \text{kWh}$$

$$\Delta \text{kWh for remaining measure life (next 12 years):}$$

$$= \left( \frac{903 \times 36,000 \times (1/14 - 1/15)}{1000} \right) + \left( \frac{1,288 \times 36,000 \times (1/8.2 - 1/9)}{1000} \right)$$

$$= 657 \text{kWh}$$

---

177 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).

## 5.3.1 Air Source Heat Pump

### Existing Cooling System

<table>
<thead>
<tr>
<th>System Type</th>
<th>EER_exist&lt;sup&gt;179&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.55</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.15</td>
</tr>
<tr>
<td>No central cooling&lt;sup&gt;180&lt;/sup&gt;</td>
<td>Make ‘1/EER_exist’ = 0</td>
</tr>
</tbody>
</table>

EER<sub>base</sub> = Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/hr / kW)  
= 11.8<sup>181</sup>

EER<sub>ee</sub> = Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/hr / kW)  
= Actual, If not provided convert SEER to EER using this formula:<sup>182</sup>  
= (-0.02 * SEER<sub>ee</sub>^2) + (1.12 * SEER<sub>ee</sub>)

CF<sub>SSP, SF</sub> = Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during system peak hour)  
= 72%<sup>183</sup>

CF<sub>PJM, SF</sub> = PJM Summer Peak Coincidence Factor for Heat Pumps in single-family homes (average during peak period)  
= 46.6%<sup>184</sup>

CF<sub>SSP, MF</sub> = Summer System Peak Coincidence Factor for Heat Pumps in multi-family homes (during system peak hour)  
= 67%<sup>185</sup>

CF<sub>PJM, MF</sub> = PJM Summer Peak Coincidence Factor for Heat Pumps in multi-family homes (average during peak period)  
= 28.5%<sup>35</sup>

---

179 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

180 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.

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


183 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

184 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

185 All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015
**Air Source Heat Pump**

### Time of Sale:

For example, a three ton, 15 SEER, 12 EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion:

\[
\Delta kW_{SSP} = \left((36,000 \times (1/11.8 - 1/12)) / 1000 \right) \times 0.72 \\
= 0.037 \text{ kW}
\]

\[
\Delta kW_{PJM} = \left((36,000 \times (1/11.8 - 1/12)) / 1000 \right) \times 0.466 \\
= 0.024 \text{ kW}
\]

### Early Replacement:

For example, a three ton, 15 SEER, 12 EER, 9 HSPF Air Source Heat Pump replaces an existing working Air Source Heat Pump with unknown efficiency ratings in single-family home in Marion:

\[
\Delta kW_{SSP} \text{ for remaining life of existing unit (1st 6 years)}: \\
= \left((36,000 \times (1/8.55 - 1/12)) / 1000 \right) \times 0.72 \\
= 0.872 \text{ kW}
\]

\[
\Delta kW_{SSP} \text{ for remaining measure life (next 12 years)}: \\
= \left((36,000 \times (1/11.8 - 1/12)) / 1000 \right) \times 0.72 \\
= 0.037 \text{ kW}
\]

\[
\Delta kW_{PJM} \text{ for remaining life of existing unit (1st 6 years)}: \\
= \left((36,000 \times (1/8.55 - 1/12)) / 1000 \right) \times 0.466 \\
= 0.564 \text{ kW}
\]

\[
\Delta kW_{PJM} \text{ for remaining measure life (next 12 years)}: \\
= \left((36,000 \times (1/11.8 - 1/12)) / 1000 \right) \times 0.466 \\
= 0.024 \text{ kW}
\]

---

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-HVC-ASHP-V07-180101

**REVIEW DEADLINE:** 1/1/2021
5.3.2 Boiler Pipe Insulation

**DESCRIPTION**
This measure describes adding insulation to un-insulated boiler pipes in un-conditioned basements or crawlspaces. This measure was developed to be applicable to the following program types: TOS, RNC, RF, DI. If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**
The efficient case is installing pipe wrap insulation to a length of boiler pipe.

**DEFINITION OF BASELINE EQUIPMENT**
The baseline is an un-insulated boiler pipe.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The measure life is assumed to be 15 years\(^{186}\).

**DEEMED MEASURE COST**
The measure cost including material and installation is assumed to be $3 per linear foot\(^ {187}\).

**LOADSHAPE**
N/A

**COINCIDENCE FACTOR**
N/A

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**
N/A

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**
N/A

**NATURAL GAS SAVINGS**

\[\Delta \text{Therm} = (((1/R_{\text{exist}} \cdot C_{\text{exist}}) - (1/R_{\text{new}} \cdot C_{\text{new}})) \cdot FLH_{\text{heat}} \cdot L \cdot \Delta T) / \eta_{\text{Boiler}} \cdot 100,000\]

Where:

\[R_{\text{exist}} = \text{Pipe heat loss coefficient of uninsulated pipe (existing) [hr-°F-ft²]/Btu}\]

---


\(^{187}\) Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
\[ R_{\text{new}} = 0.5^{188} \]

\[ R_{\text{new}} = \text{Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft²)/Btu]} \]

\[ = \text{Actual (0.5 + R value of insulation)} \]

\[ \text{FLH}_{\text{heat}} = \text{Full load hours of heating} \]

\[ = \text{Dependent on location}^{189}; \]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_{\text{heat}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,969</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,840</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,754</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,266</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,288</td>
</tr>
<tr>
<td>Weighted Average(^{190})</td>
<td>1,821</td>
</tr>
</tbody>
</table>

\[ L = \text{Length of boiler pipe in unconditioned space covered by pipe wrap (ft)} \]

\[ = \text{Actual} \]

\[ C_{\text{exist}} = \text{Circumference of bare pipe (ft) (Diameter (in) * π/12)} \]

\[ = \text{Actual (0.5” pipe = 0.131ft, 0.75” pipe = 0.196ft)} \]

\[ C_{\text{new}} = \text{Circumference of pipe with insulation (ft) ([Diameter of pipe (in)] + ([Thickness of Insulation (in)]*2)) * π/12)} \]

\[ = \text{Actual} \]

\[ ΔT = \text{Average temperature difference between circulated heated water and unconditioned space air temperature (°F)}^{191} \]

Pipes in unconditioned basement:

<table>
<thead>
<tr>
<th>Outdoor reset controls</th>
<th>ΔT (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler without reset control</td>
<td>110</td>
</tr>
<tr>
<td>Boiler with reset control</td>
<td>70</td>
</tr>
</tbody>
</table>

Pipes in crawl space:

\(^{188}\) Assumption based on data obtained from the 3E Plus heat loss calculation software provided by the NAIMA (North American Insulation Manufacturer Association) and derived from Table 15 and Table 16 of 2009 ASHRAE Fundamentals Handbook, Chapter 23 Insulation for Mechanical Systems, page 23.17.

\(^{189}\) Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the Energy Star Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider Energy Star estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from http://www.icc.illinois.gov/ags/consumereducation.aspx) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_{heat} of 1821 hours. We used the ratio of this value to the average of the locations using the Energy Star data (1994 hours) to scale down the Energy Star estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\(^{190}\) Weighted based on number of occupied residential housing units in each zone.

\(^{191}\) Assumes 160°F water temp for a boiler without reset control, 120°F for a boiler with reset control, and 50°F air temperature for pipes in unconditioned basements and the following average heating season outdoor temperatures as the air temperature in crawl spaces: Zone 1 – 33.1, Zone 2 – 34.4, Zone 3 – 37.7, Zone 4 – 40.0, Zone 5 – 39.8, Weighted Average – 35.3 (NCDC 1881-2010 Normals, average of monthly averages Nov – Apr for zones 1-3 and Nov-March for zones 4 and 5).
### Climate Zone (City based upon) \( \Delta T \) (°F) 

<table>
<thead>
<tr>
<th></th>
<th>Boiler without reset control</th>
<th>Boiler with reset control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>127</td>
<td>87</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>126</td>
<td>86</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>122</td>
<td>82</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>120</td>
<td>80</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>120</td>
<td>80</td>
</tr>
<tr>
<td>Weighted Average(^{192})</td>
<td>125</td>
<td>85</td>
</tr>
</tbody>
</table>

\( \eta_{\text{Boiler}} \) = Efficiency of boiler

\[ \eta_{\text{Boiler}} = 0.819 \] \(^{193}\)

For example, insulating 10 feet of 0.75" pipe with R-3 wrap (0.75" thickness) in a crawl space of a Marion home with a boiler without reset control:

\[
\Delta \text{Therm} = \frac{((1/0.5 \times 0.196) - (1/3.5 \times 0.589)) \times 10 \times 120 \times 1288}{0.819 / 100,000} = 4.2 \text{ therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-HVC-PINS-V02-160601

**REVIEW DEADLINE:** 1/1/2022

---

\(^{192}\) Weighted based on number of occupied residential housing units in each zone.

\(^{193}\) Average efficiency of boiler units found in Ameren PY3-PY4 data.
5.3.3 Central Air Conditioning

**DESCRIPTION**

This measure characterizes:

a) **Time of Sale:**

   a. The installation of a new residential sized (<= 65,000 Btu/hr) Central Air Conditioning ducted split system meeting ENERGY STAR efficiency standards presented below. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) **Early Replacement:**

   Early Replacement determination will be based on meeting the following conditions:
   
   • The existing unit is operational when replaced, or
   • The existing unit requires minor repairs (<$190 per ton)\(^{194}\). 
   • All other conditions will be considered Time of Sale.

   The Baseline SEER of the existing Central Air Conditioning unit replaced:
   
   • If the SEER of the existing unit is known and <=10, the Baseline SEER is the actual SEER value of the unit replaced. If the SEER is >10, the Baseline SEER = 13.
   • If the SEER of the existing unit is unknown, use assumptions in variable list below (SEER\(_{exist}\)).
   • If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

   A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown\(^{195}\).

**Deemed Early Replacement Rates For CAC Units in Combined System Replacement (CSR) Projects**

<table>
<thead>
<tr>
<th>Replacement Scenario for the CAC Unit</th>
<th>Deemed Early Replacement Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Replacement Rate for a CAC unit when the CAC unit is the Primary unit in a CSR project</td>
<td>14%</td>
</tr>
<tr>
<td>Early Replacement Rate for a CAC unit when the CAC unit is the Secondary unit in a CSR project</td>
<td>40%</td>
</tr>
</tbody>
</table>

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

---

\(^{194}\) The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

\(^{195}\) Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the “primary unit”. The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the “secondary unit”. This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < $550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014, available at http://www.ilsag.info/evaluation-documents.html.
DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the efficient equipment is assumed to be a ducted split central air conditioning unit meeting the minimum ENERGY STAR efficiency level standards; 14.5 SEER and 12 EER.

DEFINITION OF BASELINE EQUIPMENT

The baseline for the Time of Sale measure is based on the current Federal Standard efficiency level; 13 SEER and 11 EER.

The baseline 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\textsuperscript{196} for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years\textsuperscript{197}.

Remaining life of existing equipment is assumed to be 6 years\textsuperscript{198}.

DEEMED MEASURE COST

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below\textsuperscript{199}:

<table>
<thead>
<tr>
<th>Efficiency Level (SEER)</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>$0</td>
</tr>
<tr>
<td>15</td>
<td>$108</td>
</tr>
<tr>
<td>16</td>
<td>$221</td>
</tr>
<tr>
<td>17</td>
<td>$620</td>
</tr>
<tr>
<td>18</td>
<td>$620</td>
</tr>
</tbody>
</table>

Early replacement: The full install cost for this measure is the actual cost of removing the existing unit and installing the new one. If this is unknown, assume defaults below\textsuperscript{200}.

<table>
<thead>
<tr>
<th>Efficiency Level (SEER)</th>
<th>Full Retrofit Cost (including labor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>$952 / ton + $0</td>
</tr>
<tr>
<td>15</td>
<td>$952 / ton + $108</td>
</tr>
<tr>
<td>16</td>
<td>$952 / ton + $221</td>
</tr>
<tr>
<td>17</td>
<td>$952 / ton + $620</td>
</tr>
<tr>
<td>18</td>
<td>$952 / ton + $620</td>
</tr>
</tbody>
</table>

\textsuperscript{196}Baseline SEER and EER should be updated when new minimum federal standards become effective.


\textsuperscript{198}Assumed to be one third of effective useful life

\textsuperscript{199}Based on incremental cost results from Cadmus “HVAC Program: Incremental Cost Analysis Update”, December 19, 2016.

\textsuperscript{200}Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857 (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls). Efficiency cost increment consistent with Cadmus study results.
Assumed deferred cost (after 6 years) of replacing existing equipment with new baseline unit is assumed to be $3,140\textsuperscript{201}. This cost should be discounted to present value using the nominal societal discount rate.

**Loadshape**

Loadshape R08 - Residential Cooling

**Coincidence Factor**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
\begin{align*}
CF_{SSP} & = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)} \\
& = 68\%\textsuperscript{202} \\
CF_{PJM} & = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \\
& = 46.6\%\textsuperscript{203}
\end{align*}
\]

**Algorithm**

**Calculation of Savings**

**Electric Energy Savings**

Time of sale:

\[
\Delta k\text{WHR} = (FLH\text{cool} * \text{Btu/hr} * (1/\text{SEERbase} - 1/\text{SEERee}))/1000
\]

Early replacement\textsuperscript{204}:

\[
\begin{align*}
\Delta k\text{WHR for remaining life of existing unit (1st 6 years)}: \\
& =((FLH\text{cool} * \text{Capacity} * (1/\text{SEERexist} - 1/\text{SEERee}))/1000); \\
\Delta k\text{WHR for remaining measure life (next 12 years)}: \\
& = ((FLH\text{cool} * \text{Capacity} * (1/\text{SEERbase} - 1/\text{SEERee}))/1000)
\end{align*}
\]

Where:

\[
\begin{align*}
FLH\text{cool} & = \text{Full load cooling hours} \\
& = \text{dependent on location and building type}\textsuperscript{205}.
\end{align*}
\]

\textsuperscript{201} Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator, $2,857, and applying inflation rate of 1.91% (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CaC_CAC.xls). While baselines are likely to shift in the future, there is currently no good indication of what the cost of a new baseline unit will be in 6 years. In the absence of this information, assuming a constant federal baseline cost is within the range of error for this prescriptive measure.

\textsuperscript{202} Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\textsuperscript{203} Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\textsuperscript{204} 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).

\textsuperscript{205} Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency
Climate Zone (City based upon) | FLHcool (single family) | FLHcool (multi family) \\
--- | --- | --- \\
1 (Rockford) | 512 | 467 \\
2 (Chicago) | 570 | 506 \\
3 (Springfield) | 730 | 663 \\
4 (Belleville) | 1035 | 940 \\
5 (Marion) | 903 | 820 \\
Weighted Average$^{206}$ | 629 | 564 \\

Capacity = Size of new equipment in Btu/hr (note 1 ton = 12,000 Btu/hr) 
= Actual installed, or if actual size unknown 33,600 Btu/hr for single-family buildings$^{207}$

SEERbase = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh) 
= 13$^{208}$

SEERexist = Seasonal Energy Efficiency Ratio of existing unit (kBtu/kWh) 
= Use actual SEER rating where it is possible to measure or reasonably estimate. If unknown assume 10.0$^{209}$.

SEERee = Seasonal Energy Efficiency Ratio of ENERGY STAR unit (kBtu/kWh) 
= Actual installed or 14.5 if unknown

Time of sale example: a 3 ton unit with SEER rating of 14.5, in unknown location:
\[
\Delta \text{kWH} = \left(\frac{629 \times 36,000 \times (1/13 - 1/14.5)}{1000}\right)
\]
\[
= 180 \text{kWh}
\]

Early replacement example: a 3 ton unit, with SEER rating of 14.5 replaces an existing unit in unknown location:
\[
\Delta \text{kWH (for first 6 years)} = \left(\frac{629 \times 36,000 \times (1/10 - 1/14.5)}{1000}\right)
\]
\[
= 702 \text{kWh}
\]
\[
\Delta \text{kWH (for next 12 years)} = \left(\frac{629 \times 36,000 \times (1/13 - 1/14.5)}{1000}\right)
\]
\[
= 180 \text{kWh}
\]
Therefore savings adjustment of 26% (180/702) after 6 years.

---

Services (CACES), 2010, Navigant Consulting”, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

$^{206}$ Weighted based on number of residential occupied housing units in each zone.

$^{207}$ Actual unit size required for multi-family building, no size assumption provided because the unit size and resulting savings can vary greatly depending on the number of units.


$^{209}$ VEIC estimate based on Department of Energy Federal Standard between 1992 and 2006. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Time of sale:

\[ \Delta kW = \frac{(\text{Capacity} \times (1/\text{EERbase} - 1/\text{EERee}))}{1000} \times \text{CF} \]

Early replacement\(^{210}\):

\[ \Delta kW \text{ for remaining life of existing unit (1st 6 years)}: \]

\[ = \frac{(\text{Capacity} \times (1/\text{EERexist} - 1/\text{EERee}))}{1000} \times \text{CF}; \]

\[ \Delta kW \text{ for remaining measure life (next 12 years)}: \]

\[ = \frac{(\text{Capacity} \times (1/\text{EERbase} - 1/\text{EERee}))}{1000} \times \text{CF} \]

Where:

- **EERbase** = EER Efficiency of baseline unit
  - = 11.2 \(^{211}\)
- **EERexist** = EER Efficiency of existing unit
  - = Actual EER of unit should be used, if EER is unknown, use 9.2 \(^{212}\)
- **EERee** = EER Efficiency of ENERGY STAR unit
  - = Actual installed or 12 if unknown
- **CF\(_{SSP}\)** = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
  - = 68\% \(^{213}\)
- **CF\(_{PJM}\)** = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)
  - = 46.6\% \(^{214}\)

\(^{210}\) 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).

\(^{211}\) The federal Standard does not currently include an EER component. The value is approximated based on the SEER standard (13) and equals EER 11.2. To perform this calculation we are using this formula: \((-0.02 \times \text{SEER}^2) + (1.12 \times \text{SEER})\) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).

\(^{212}\) Based on SEER of 10,0, using formula above to give 9.2 EER.

\(^{213}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{214}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
<table>
<thead>
<tr>
<th>Measure Code: RS-HVC-CAC1-V07-180101</th>
<th>Review Deadline: 1/1/2021</th>
</tr>
</thead>
</table>

### Time of sale example:

A 3 ton unit with EER rating of 12:

\[
\Delta kW_{SSP} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.68} = 0.146 \text{ kW}
\]

\[
\Delta kW_{PJM} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.466} = 0.100 \text{ kW}
\]

### Early replacement example:

A 3 ton unit with EER rating of 12 replaces an existing unit:

\[
\Delta kW_{SSP} \text{ (for first 6 years)} = \frac{(36,000 \times (1/9.2 - 1/12))}{1000 \times 0.68} = 0.621 \text{ kW}
\]

\[
\Delta kW_{SSP} \text{ (for next 12 years)} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.68} = 0.146 \text{ kW}
\]

\[
\Delta kW_{PJM} \text{ (for first 6 years)} = \frac{(36,000 \times (1/9.2 - 1/12))}{1000 \times 0.466} = 0.425 \text{ kW}
\]

\[
\Delta kW_{PJM} \text{ (for next 12 years)} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.466} = 0.100 \text{ kW}
\]
5.3.4 Duct Insulation and Sealing

DESCRIPTION

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

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


2. Evaluation of Distribution Efficiency – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes ‘Distribution Efficiency Look-Up Table’;
   a. Percentage of duct work found within the conditioned space
   b. Duct leakage evaluation
   c. Duct insulation evaluation

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

The efficient condition is sealed duct work throughout the unconditioned or semi-conditioned space in the home. A non-conditioned space is defined as a space outside of the thermal envelope of the building that is not intentionally heated for occupancy (crawl space, roof attic, etc). A semi-conditioned space is defined as a space within the thermal envelop that is not intentionally heated for occupancy (unfinished basement)\(^2\).

DEFINITION OF BASELINE EQUIPMENT

The existing baseline condition is leaky duct work within the unconditioned or semi-conditioned space in the home.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The assumed lifetime of this measure is 20 years\(^2\).

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat


COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
\begin{align*}
CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \\
&= 68\%^{217} \\
CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \\
&= 46.6\%^{218}
\end{align*}
\]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Modified Blower Door Subtraction

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

\[
\text{Duct Leakage (CFM}_{50DL} = (\text{CFM}_{50\text{Whole House}} - \text{CFM}_{50\text{Envelope Only}}) \times \text{SCF}
\]

Where:

\[
\begin{align*}
\text{CFM}_{50\text{Whole House}} &= \text{Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential} \\
\text{CFM}_{50\text{Envelope Only}} &= \text{Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.} \\
\text{SCF} &= \text{Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.}
\end{align*}
\]

b) Calculate duct leakage reduction, convert to CFM25DL and factor in Supply and Return Loss Factors

\[
\text{Duct Leakage Reduction (}\Delta\text{CFM}_{25DL} = (\text{Pre CFM}_{50DL} - \text{Post CFM}_{50DL}) \times 0.64 \times (\text{SLF + RLF})
\]

Where:

\[
\begin{align*}
0.64 &= \text{Converts CFM50 to CFM25}^{219} \\
\text{SLF} &= \text{Supply Loss Factor}
\end{align*}
\]

---

217 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
218 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
219 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the “Can’t Reach Fifty” factor for CFM25; see Energy Conservatory Blower Door Manual).
= % leaks sealed located in Supply ducts * 1

Default = 0.5

RLF = Return Loss Factor

= % leaks sealed located in Return ducts * 0.5

Default = 0.25

c) Calculate Electric Energy Savings:

\[ \Delta kWh = \Delta kWh_{cooling} + \Delta kWh_{Fan} \]

\[ \Delta kWh_{cooling} = (\frac{\Delta CFM_{25DL}}{(\text{CapacityCool}/12,000) * 400}) * FLH_{cool} * \text{CapacityCool} * TRF_{cool} / 1000 / \eta_{cool} \]

\[ \Delta kWh_{Fan} = (\Delta Therms \times F_e \times 29.3) \]

Where:

\( \Delta CFM_{25DL} \) = Duct leakage reduction in CFM25

= calculated above

\( \text{CapacityCool} \) = Capacity of Air Cooling system (Btu/hr)

=Actual

12,000 = Converts Btu/H capacity to tons

400 = Converts capacity in tons to CFM (400CFM / ton)

\( FLH_{cool} \) = Full load cooling hours

= Dependent on location as below:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHcool Single Family</th>
<th>FLHcool Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>312</td>
<td>467</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
</tbody>
</table>

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

Assumes 50% of leaks are in supply ducts.

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

Assumes 50% of leaks are in return ducts.

This conversion is an industry rule of thumb; e.g. see http://www.hvacsalesandsupply.com/Linked%20Documents/Tech%20Tips/61-Why%20400%20CFM%20per%20ton.pdf

Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
5.3.4 Duct Insulation and Sealing

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHcool Single Family</th>
<th>FLHcool Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average226</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

TRFcool = Thermal Regain Factor for cooling by space type
= 1.0 for Unconditioned Spaces
= 0.0 for Semi-Conditioned Spaces227

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)
= Actual. If unknown assume the following228:

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>SEER Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>After 2006 - 2014</td>
<td>13</td>
</tr>
<tr>
<td>Central AC After 1/1/2015</td>
<td>13</td>
</tr>
<tr>
<td>Heat Pump After 1/1/2015</td>
<td>14</td>
</tr>
</tbody>
</table>

ΔTherms = Therm savings as calculated in Natural Gas Savings

F_e = Furnace Fan energy consumption as a percentage of annual fuel consumption
= 3.14%229

29.3 = kWh per therm

---

226 Weighted based on number of occupied residential housing units in each zone.
227 Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
228 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.
229 F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.
For example, duct sealing in unconditioned space a single family house in Springfield with a 36,000 Btu/H, SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following blower door test results:

**Before:**
- $CFM_{50, \text{Whole House}} = 4800$ CFM50
- $CFM_{50, \text{Envelope Only}} = 4500$ CFM50

House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

**After:**
- $CFM_{50, \text{Whole House}} = 4600$ CFM50
- $CFM_{50, \text{Envelope Only}} = 4500$ CFM50

House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

**Duct Leakage:**
- $CFM_{DL, \text{before}} = (4800 - 4500) \times 1.29$
  = 387 CFM
- $CFM_{DL, \text{after}} = (4600 - 4500) \times 1.39$
  = 139 CFM

Duct Leakage reduction at CFM25:
- $\Delta CFM_{25, DL} = (387 - 139) \times 0.64 \times (0.5 + 0.25)$
  = 119 CFM25

**Energy Savings:**
- $\Delta kWh_{\text{cooling}} = \frac{((119 / ((36,000/12,000) \times 400)) \times 730 \times 36,000 \times 1)}{1000 / 11} + (212 \times 0.0314 \times 29.3)$
  = 237 + 195
  = 432 kWh

**Heating savings for homes with electric heat:**

$$\Delta kWh_{\text{heating}} = \frac{((\Delta CFM_{25, DL} / ((\text{OutputCapacityHeat}/12,000) \times 400)) \times \text{FLHheat} \times \text{OutputCapacityHeat} \times \text{TRFheat}}{\eta_{\text{heat}} / 3412}$$

Where:
- OutputCapacityHeat = Heating output capacity (Btu/hr) of electric heat
  = Actual
- FLHheat = Full load heating hours
  = Dependent on location as below:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,969</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,840</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,754</td>
</tr>
</tbody>
</table>

230 Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.
**Illinois Statewide Technical Reference Manual – 5.3.4 Duct Insulation and Sealing**

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (Belleville)</td>
<td>1,266</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,288</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>1,821</td>
</tr>
</tbody>
</table>

\[ \text{TRF}_{\text{heat}} = \text{Thermal Regain Factor for heating by space type} \]
\[ \text{TRF}_{\text{heat}} = 0.40 \text{ for Semi-Conditioned Spaces} \]
\[ \text{TRF}_{\text{heat}} = 1.0 \text{ for Unconditioned Spaces} \]

\[ \eta_{\text{Heat}} = \text{Efficiency in COP of Heating equipment} \]
\[ \eta_{\text{Heat}} = \text{Actual. If not available use}^{233} : \]

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>2.26</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.40</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
</tbody>
</table>

3412 = Converts Btu to kWh

For example, duct sealing in unconditioned space in a 36,000 Btu/H 2.5 COP heat pump heated single family house in Springfield with the blower door results described above:

\[ \Delta \text{kWh}_{\text{heating}} = \left( \frac{119}{(36,000/12,000) \times 400} \right) \times 1,754 \times 36,000 \times 1 / 2.5 / 3412 \]
\[ \Delta \text{kWh}_{\text{heating}} = 734 \text{ kWh} \]

**Methodology 2: Evaluation of Distribution Efficiency**

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

\[ \Delta \text{kWh} = \left( \frac{( \text{DE}_{\text{after}} - \text{DE}_{\text{before}} ) \times \text{FLH}_{\text{cool}} \times \text{Capacity}_{\text{cool}} \times \text{TRF}_{\text{cool}}}{1000 \times \eta_{\text{cool}}} \right) + (\Delta \text{Therms} \times \text{FE} \times 29.3) \]

Where:

\[ \text{DE}_{\text{after}} = \text{Distribution Efficiency after duct sealing} \]
\[ \text{DE}_{\text{before}} = \text{Distribution Efficiency before duct sealing} \]

---

231 Weighted based on number of occupied residential housing units in each zone.
232 Thermal regain (i.e. the potential for conditioned air escaping from ducts not being lost to the atmosphere) for residential pipe insulation measures is discussed in Home Energy Services Impact Evaluation, prepared for the Massachusetts Residential Retrofit and Low Income Program Area Evaluation, Cadmus Group, Inc., August 2012.
233 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.
FLHcool = Full load cooling hours

= Dependent on location as below:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHcool Single Family</th>
<th>FLHcool Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

CapacityCool = Capacity of Air Cooling system (Btu/hr)

= Actual

TRFcool = Thermal Regain Factor for cooling by space type

= 1.0 for Unconditioned Spaces
= 0.0 for Semi-Conditioned Spaces

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual. If unknown assume:

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>SEER Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>After 2006 - 2014</td>
<td>13</td>
</tr>
<tr>
<td>Central AC After 1/1/2015</td>
<td>13</td>
</tr>
<tr>
<td>Heat Pump After 1/1/2015</td>
<td>14</td>
</tr>
</tbody>
</table>

234 Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

235 Weighted based on number of occupied residential housing units in each zone.


237 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.
For example, duct sealing in unconditioned space in a single family house in Springfield, with 36,000 Btu/H SEER 11 central air conditioning, an 80% AFUE, 105,000 Btu/H natural gas furnace and the following duct evaluation results:

\[
\begin{align*}
DE_{\text{before}} &= 0.85 \\
DE_{\text{after}} &= 0.92
\end{align*}
\]

Energy Savings:

\[
\Delta kWh_{\text{cooling}} = \left(\frac{(0.92 - 0.85)/(0.92)}{0.92}\right) \times 730 \times 36,000 \times 1 / 1000 / 11 + (212 \times 0.0314 \times 29.3)
\]

\[
= 182 + 195
\]

\[
= 377 \text{ kWh}
\]

Heating savings for homes with electric heat:

\[
\Delta kWh_{\text{heating}} = \left(\frac{(DE_{\text{after}} - DE_{\text{before}})}{DE_{\text{after}}}\right) \times FLH_{\text{heat}} \times OutputCapacityHeat \times TRF_{\text{heat}} \times \eta_{\text{heat}} / 3412
\]

Where:

- OutputCapacityHeat = Heating output capacity (Btu/hr) of the electric heat
  = Actual
- FLH_{\text{heat}} = Full load heating hours
  = Dependent on location as below\(^{238}\):

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_{\text{heat}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,969</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,840</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,754</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,266</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,288</td>
</tr>
<tr>
<td>Weighted Average(^{239})</td>
<td>1,821</td>
</tr>
</tbody>
</table>

- TRF_{\text{heat}} = Thermal Regain Factor for heating by space type
  = 0.40 for Semi-Conditioned Spaces
  = 1.0 for Unconditioned Spaces\(^{240}\)
- COP = Coefficient of Performance of electric heating system\(^{241}\)
  = Actual. If not available use\(^{242}\):

\(^{238}\) Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.

\(^{239}\) Weighted based on number of occupied residential housing units in each zone.


\(^{241}\) Note that the HSPF of a heat pump is equal to the COP * 3.413.

\(^{242}\) These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for
### System Type

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
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<td>6.8</td>
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</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.40</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
</tbody>
</table>

For example, duct sealing in unconditioned space in a 36,000 Btu/H, 2.5 COP heat pump heated single family house in Springfield with the following duct evaluation results:

\[
DE_{after} = 0.92 \\
DE_{before} = 0.85
\]

Energy Savings:

\[
\Delta kWh_{heating} = \frac{(0.92 - 0.85)/0.92) \times 1,754 \times 36,000 \times 1)}{2.5} / 3412
\]

\[
= 563 \text{ kWh}
\]

### Summer Coincident Peak Demand Savings

\[
\Delta kW = \Delta kWh_{cooling}/ FLHcool \times CF
\]

Where:

\[
FLHcool = \text{Full load cooling hours:}
\]

\[
= \text{Dependent on location as below}^{243}:
\]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHcool Single Family</th>
<th>FLHcool Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
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<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average\text{\textsuperscript{244}}</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

\[
CF_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)}
\]

\[
CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)}
\]

\[
= 68\%^{245}
\]

\[
= 46.6\%^{246}
\]

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.

\textsuperscript{243} Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{244} Weighted based on number of occupied residential housing units in each zone.

\textsuperscript{245} Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\textsuperscript{246} Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
**NATURAL GAS SAVINGS**

For homes with Natural Gas Heating:

**Methodology 1: Modified Blower Door Subtraction**

\[
\Delta \text{Therm} = \frac{\left(\frac{\Delta \text{CFM25}_{DL}}{(\text{InputCapacityHeat} \times 0.0123)} \times \text{FLH}_{\text{heat}} \times \text{InputCapacityHeat} \times \text{TRF}_{\text{heat}} \times \left(\frac{\eta_{\text{Equipment}}}{\eta_{\text{System}}}\right)\right)}{100,000}
\]

Where:

- \(\Delta \text{CFM25}_{DL}\) = Duct leakage reduction in CFM25
- InputCapacityHeat = Heating input capacity (Btu/hr) = Actual
- 0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)
- FLHheat = Full load heating hours = Dependent on location as below:
<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,969</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,840</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,754</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,266</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,288</td>
</tr>
<tr>
<td>Weighted Average(^{249})</td>
<td>1,821</td>
</tr>
</tbody>
</table>
- TRFheat = Thermal Regain Factor for heating by space type
  - 0.40 for Semi-Conditioned Spaces
  - 1.0 for Unconditioned Spaces\(^{250}\)
- \(\eta_{\text{Equipment}}\) = Heating Equipment Efficiency
- 100,000 = Converts Btu to therms

\(^{247}\) Based on Natural Draft Furnaces requiring 100 CFM per 10,000 Btu, Induced Draft Furnaces requiring 130CFM per 10,000Btu and Condensing Furnaces requiring 150 CFM per 10,000 Btu (rule of thumb from http://contractingbusiness.com/enewletters/cb_imp_43580/). Data provided by GAMA during the federal rule-making process for furnace efficiency standards, suggested that in 2000, 24% of furnaces purchased in Illinois were condensing units. Therefore a weighted average required airflow rate is calculated assuming a 50:50 split of natural v induced draft non-condensing furnaces, as 123 per 10,000Btu or 0.0123/Btu.

\(^{248}\) Heating EFLH based on ENERGY Star EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL.

\(^{249}\) Weighted based on number of occupied residential housing units in each zone.

The Equipment Efficiency can be obtained either by recording the AFUE of the unit, or performing a steady state efficiency test.

If there are more than one heating systems, the weighted (by consumption) average efficiency should be used.

If the heating system or distribution is being upgraded within a package of measures together with the insulation upgrade, the new average heating system efficiency should be used.

This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (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))

In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[
(0.24 \times 0.92) + (0.76 \times 0.8) = 0.829
\]

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.

Estimated as follows: 0.829 * (1-0.15) = 0.70
For example, duct sealing in unconditioned space in a house in Springfield with an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following blower door test results:

Before:  
- CFM50\textsubscript{Whole House} = 4800 CFM50
- CFM50\textsubscript{Envelope Only} = 4500 CFM50
- House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After:  
- CFM50\textsubscript{Whole House} = 4600 CFM50
- CFM50\textsubscript{Envelope Only} = 4500 CFM50
- House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:

\[
\begin{align*}
\text{CFM50}_{DL \text{ before}} &= (4800 - 4500) \times 1.29 \\
&= 387 \text{ CFM} \\
\text{CFM50}_{DL \text{ after}} &= (4600 - 4500) \times 1.39 \\
&= 119 \text{ CFM}
\end{align*}
\]

Duct Leakage reduction at CFM25:

\[
\begin{align*}
\Delta\text{CFM25}_{DL} &= (387 - 139) \times 0.64 \times (0.5 + 0.25) \\
&= 119 \text{ CFM25}
\end{align*}
\]

Energy Savings:

- Pre Distribution Efficiency = 1 - (387/4800) = 92%
- η\text{System} = 80% * 92% = 74%
- \Delta\text{Therm} = ((119/ (105,000 * 0.0123)) \times 1,754 \times 105,000 \times 1 \times (0.8/0.74)) / 100,000
  = 183 therms

**Methodology 2: Evaluation of Distribution Efficiency**

\[
\Delta\text{Therm} = ((\text{DE}_{\text{after}} - \text{DE}_{\text{before}}) / \text{DE}_{\text{after}}) \times \text{FLHheat} \times \text{InputCapacityHeat} \times \text{TRFheat} \times (\eta\text{Equipment} / \eta\text{System}) / 100,000
\]

Where:

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

Other variables as defined above
For example, duct sealing in unconditioned space in a house in Springfield an 80% AFUE, 105,000 Btu/H (input capacity) natural gas furnace and the following duct evaluation results:

\[
\begin{align*}
DE_{after} &= 0.92 \\
DE_{before} &= 0.85
\end{align*}
\]

Energy Savings:

\[
\begin{align*}
\eta_{System} &= 80\% \times 85\% = 68\% \\
\Delta\text{Therm} &= \frac{((0.92 - 0.85)/0.92) \times 1,754 \times 105,000 \times 1 \times (0.8/0.68))}{100,000} \\
&= 164 \text{ therm}
\end{align*}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-DINS-V06-160601**

**REVIEW DEADLINE: 1/1/2022**
5.3.5 Furnace Blower Motor

DESCRIPTION

A new furnace with a brushless permanent magnet (BPM) blower motor is installed instead of a new furnace with a lower efficiency motor. This measure characterizes only the electric savings associated with the fan and could be coupled with gas savings associated with a more efficient furnace. Savings decrease sharply with static pressure so duct improvements, and clean, low pressure drop filters can maximize savings. Savings improve when the blower is used for cooling as well and when it is used for continuous ventilation, but only if the non-BPM motor would have been used for continuous ventilation too. If the resident runs the BPM blower continuously because it is a more efficient motor and would not run a non-BPM motor that way, savings are near zero and possibly negative. This characterization uses a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin, which accounted for the effects of this behavioral impact.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

A furnace with a brushless permanent magnet (BPM) blower motor, also known by the trademark ECM, BLDC, and other names.

DEFINITION OF BASELINE EQUIPMENT

A furnace with a non-BPM blower motor.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 20 years\textsuperscript{255}.

DEEMED MEASURE COST

The capital cost for this measure is assumed to be $97\textsuperscript{256}.

LOADSHAPE

- Loadshape R08 - Residential Cooling
- Loadshape R09 - Residential Electric Space Heat
- Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
CF_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)}
\]

\[
= 68\% \textsuperscript{257}
\]

\textsuperscript{255} Consistent with assumed life of a new gas furnace. Table 8.3.3 The Technical support documents for federal residential appliance standards: \url{http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf}

\textsuperscript{256} Adapted from Tables 8.2.3 and 8.2.13 in \url{http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_08_lcc_2011-06-24.pdf}

\textsuperscript{257} Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
Illinois Statewide Technical Reference Manual – 5.3.5 Furnace Blower Motor

\[
\text{CF}_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)}
\]
\[
= 46.6\%^{258}
\]

---

**Algorithm**

---

**Calculation of Savings**

**Electric Energy Savings**

\[ \Delta \text{kWh} = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings} \]

Where:

- **Heating Savings** = Blower motor savings during heating season
  \[ = 418 \text{ kWh}^{259} \]

- **Cooling Savings** = Blower motor savings during cooling season
  If Central AC = 263 kWh
  If No Central AC = 175 kWh
  If unknown (weighted average) = 241 kWh^{260}

- **Shoulder Season Savings** = Blower motor savings during shoulder seasons
  = 51 kWh

For example, a blower motor in a home where Central AC presence is unknown:

\[ \Delta \text{kWh} = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings} \]
\[ = 418 + 263 + 51 \]
\[ = 732 \text{ kWh} \]

**Summer Coincident Peak Demand Savings**

\[ \Delta \text{kW} = \frac{\text{Cooling Savings}}{\text{FLH}_{\text{cooling}}} \times \text{CF} \]

Where:

- **FLH_{cooling}** = Full load hours of air conditioning
- = Dependent on location^{261}:

---

^{258} Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

^{259} To estimate heating, cooling and shoulder season savings for Illinois, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: FOE to IL Blower Savings.xlsx.

^{260} The weighted average value is based on assumption that 75% of homes installing BPM furnace blower motors have Central AC. 66% of IL housing units have CAC and 66% have gas furnaces. It is logical these two groups overlap to a large extent (like the 95% in the FOE study above).

^{261} Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency
### Climate Zone (City based upon) | FLH_cooling
---|---
1 (Rockford) | 512
2 (Chicago) | 570
3 (Springfield) | 730
4 (Belleville) | 1,035
5 (Marion) | 903
Weighted Average\(^{262}\) | 629

\( CF_{SSP} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

\( CF_{PJM} \) = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

**For example, a blower motor in a home of unknown location where Central AC prevalence is unknown:**

\[
\Delta kW_{SSP} = \frac{251}{629} \times 0.68
\]

\[
= 0.271 \text{ kW}
\]

\[
\Delta kW_{SSP} = \frac{251}{629} \times 0.466
\]

\[
= 0.186 \text{ kW}
\]

### Natural Gas Savings

\[ \Delta \text{therms}^{265} = -\text{Heating Savings} \times 0.03412 / \text{AFUE} \]

Where:

0.03412 = Converts kWh to therms

AFUE = Efficiency of the Furnace

= Actual. If unknown assume 95%\(^{266}\) if in new furnace or 64.4 AFUE% \(^{267}\) if in existing furnace

Using defaults:

For new Furnace = \[-(418 \times 0.03412) / 0.95\]

= - 15.0 therms

For existing Furnace = \[-(418 \times 0.03412) / 0.644\]

---

\(^{262}\) Weighted based on number of occupied residential housing units in each zone.

\(^{263}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{264}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\(^{265}\) The blower fan is in the heating duct so all, or very nearly all, of its waste heat is delivered to the conditioned space. Negative value since this measure will increase the heating load due to reduced waste heat.

\(^{266}\) Minimum ENERGY STAR efficiency after 2.1.2012.

\(^{267}\) Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
= - 22.1 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-FBMT-V03-150601**

**REVIEW DEADLINE: 1/1/2020**
5.3.6 Gas High Efficiency Boiler

DESCRIPTION

High efficiency boilers achieve most gas savings through the utilization of a sealed combustion chamber and multiple heat exchangers that remove a significant portion of the waste heat from flue gasses. Because multiple heat exchangers are used to remove waste heat from the escaping flue gasses, some of the flue gasses condense and must be drained.

This measure characterizes:

a) Time of Sale:
   a. The installation of a new high efficiency, gas-fired hot water boiler in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) Early Replacement:

   Early Replacement determination will be based on meeting the following conditions:
   - The existing unit is operational when replaced, or
   - The existing unit requires minor repairs (<$709).
   - All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:
   - If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 82%.
   - If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
   - If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rates are unknown.269

Deemed Early Replacement Rates For Boilers

<table>
<thead>
<tr>
<th>Early Replacement Rate for Boiler participants</th>
<th>Deemed Early Replacement Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7%</td>
</tr>
</tbody>
</table>

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

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the installed Boiler must be ENERGY STAR qualified (AFUE rated at or greater than 85% and input capacity less than 300,000 Btu/hr).

268 The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

269 Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. This is used as a reasonable proxy for boiler installations since boiler specific data is not available. Report presented to Nicor Gas Company February 27, 2014, available at http://www.ilsag.info/evaluation-documents.html.
DEFINITION OF BASELINE EQUIPMENT

Time of sale: The baseline equipment for this measure is a new, gas-fired, standard-efficiency water boiler. The current Federal Standard minimum is 82% AFUE.

Early replacement: The baseline for this 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.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years\(^{270}\).

Early replacement: Remaining life of existing equipment is assumed to be 8 years\(^{271}\).

DEEMED MEASURE COST

Time of sale: The incremental install cost for this measure is dependent on tier\(^{272}\):

<table>
<thead>
<tr>
<th>Measure Type</th>
<th>Installation Cost</th>
<th>Incremental Install Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFUE 82%</td>
<td>$3543</td>
<td>n/a</td>
</tr>
<tr>
<td>AFUE 85%</td>
<td>$4268</td>
<td>$725</td>
</tr>
<tr>
<td>(Energy Star Minimum)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFUE 90%</td>
<td>$4815</td>
<td>$1,272</td>
</tr>
<tr>
<td>AFUE 95%</td>
<td>$5328</td>
<td>$1,785</td>
</tr>
</tbody>
</table>

Early Replacement: The full installation cost is provided in the table above. The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $4,045\(^{273}\). This cost should be discounted to present value using the nominal discount rate.

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

---

\(^{270}\) Table 8.3.3 The Technical support documents for federal residential appliance standards: [http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/chapter_8.pdf)

\(^{271}\) Assumed to be one third of effective useful life

\(^{272}\) Based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor ([http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf)). Where efficiency ratings are not provided, the values are interpolated from those that are.

\(^{273}\) $3543 inflated using 1.91% rate.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

Time of Sale:

\[
\Delta \text{Therms} = \text{Gas\_Boiler\_Load} \times \text{HF} \times (1/\text{AFUE(base)} - 1/\text{AFUE(eff)})
\]

Early replacement:\n
\[
\Delta \text{Therms} \text{ for remaining life of existing unit (1st 8 years)}:\n\]

\[
= \text{Gas\_Boiler\_Load} \times \text{HF} \times (1/\text{AFUE(exist)} - 1/\text{AFUE(eff)})
\]

\[
\Delta \text{Therms} \text{ for remaining measure life (next 17 years)}:\n\]

\[
= \text{Gas\_Boiler\_Load} \times \text{HF} \times (1/\text{AFUE(base)} - 1/\text{AFUE(eff)})
\]

Where:

\[
\text{Gas\_Boiler\_Load} = \text{Estimate of annual household Load for gas boiler heated single-family homes.}
\]

If location is unknown, assume the average below.

\[
= \text{or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent.}
\]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas_Boiler Load (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1275</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1218</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1043</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>805</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>819</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>1158</strong></td>
</tr>
</tbody>
</table>

\[
\text{HF} = \text{Household factor, to adjust heating consumption for non-single-family households.}
\]

274 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).

275 Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Heating load is used to describe the household heating need, which is equal to (gas heating consumption * AFUE).

276 Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor. Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

277 The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.
**Household Type** | **HF**
--- | ---
Multi-Family | 65%\(^\text{278}\)
Actual | Custom\(^\text{279}\)

AFUE\(_\text{exist}\) = Existing Boiler Annual Fuel Utilization Efficiency Rating

- Use actual AFUE rating where it is possible to measure or reasonably estimate.
- If unknown, assume 61.6 AFUE\%\(^\text{280}\).

AFUE\(_\text{base}\) = Baseline Boiler Annual Fuel Utilization Efficiency Rating

- 82\%

AFUE\(_\text{eff}\) = Efficient Boiler Annual Fuel Utilization Efficiency Rating

- Actual. If unknown, use defaults dependent\(^\text{281}\) on tier as listed below:

<table>
<thead>
<tr>
<th>Measure Type</th>
<th>AFUE(_\text{eff})</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR*</td>
<td>87.5%</td>
</tr>
<tr>
<td>AFUE 90%</td>
<td>92.5%</td>
</tr>
<tr>
<td>AFUE 95%</td>
<td>95%</td>
</tr>
</tbody>
</table>

**Time of Sale:**

For example, a default sized ENERGY STAR boiler purchased and installed near Springfield

\[
\Delta\text{Therms} = 1043 \times (1/0.82 - 1/0.875)
\]

\[
= 80.0 \text{ Therms}
\]

**Early Replacement:**

For example, an existing function boiler with unknown efficiency is replaced with an ENERGY STAR boiler purchased and installed in Springfield.

\[
\Delta\text{Therms for remaining life of existing unit (1st 8 years)}:
\]

\[
= 1043 \times (1/0.616 - 1/0.875)
\]

\[
= 501 \text{ Therms}
\]

\[
\Delta\text{Therms for remaining measure life (next 17 years)}:
\]

\[
= (1043) \times (1/0.82 - 1/0.875)
\]

\[
= 80.0 \text{ Therms}
\]

---

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

**N/A**

---

\(^{278}\) Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes.

\(^{279}\) Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

\(^{280}\) Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

\(^{281}\) Default values per tier selected based upon the average AFUE value for the tier range except for the top tier where the minimum is used due to proximity to the maximum possible.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-GHEB-V06-180101

REVIEW DEADLINE: 1/1/2021
5.3.7 Gas High Efficiency Furnace

**DESCRIPTION**

High efficiency furnace features may include improved heat exchangers and modulating multi-stage burners.

This measure characterizes:

a) **Time of sale:**

   a. The installation of a new high efficiency, gas-fired condensing furnace in a residential location. This could relate to the replacement of an existing unit at the end of its useful life, or the installation of a new system in a new home.

b) **Early Replacement:**

   Early Replacement determination will be based on meeting the following conditions:
   
   • The existing unit is operational when replaced, or
   • The existing unit requires minor repairs (<$528)\(^{282}\).
   • All other conditions will be considered Time of Sale.

The Baseline AFUE of the existing unit replaced:

   • If the AFUE of the existing unit is known and <=75%, the Baseline AFUE is the actual AFUE value of the unit replaced. If the AFUE is >75%, the Baseline AFUE = 80%.
   • If the AFUE of the existing unit is unknown, use assumptions in variable list below (AFUE(exist)).
   • If the operational status or repair cost of the existing unit is unknown, use time of sale assumptions.

A weighted average early replacement rate is provided for use when the actual baseline early replacement rate is unknown\(^{283}\).

<table>
<thead>
<tr>
<th>Deemed Early Replacement Rates For Furnaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replacement Scenario for the Furnace</td>
</tr>
<tr>
<td>Early Replacement Rate for Furnace-only participants</td>
</tr>
<tr>
<td>Early Replacement Rate for a furnace when the furnace is the Primary unit in a Combined System Replacement (CSR) project</td>
</tr>
<tr>
<td>Early Replacement Rate for a furnace when the furnace is the Secondary unit in a CSR project</td>
</tr>
</tbody>
</table>

**Verified Quality Installation**

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and

\(^{282}\) The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement. Note the non-inflated cost is used as this would be a cost consideration in the program year.

\(^{283}\) Based upon research from “Home Energy Efficiency Rebate Program GPY2 Evaluation Report” which outlines early replacement rates for both primary and secondary central air cooling (CAC) and residential furnaces. The unit (furnace or CAC unit) that initially caused the customer to contact a trade ally is defined as the “primary unit”. The furnace or CAC unit that was also replaced but did not initially prompt the customer to contact a trade ally is defined as the “secondary unit”. This evaluation used different criteria for early replacement due to the availability of data after the fact; cost of any repairs < $550 and age of unit < 20 years. Report presented to Nicor Gas Company February 27, 2014, available at http://www.ilsag.info/evaluation-documents.html.
BTU measurement to ensure that newly installed equipment is operating according to manufacturers’ published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Install identifies sub-optimal performance and prescribes a solution during furnace installation.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a residential sized (input energy less than 225,000 Btu/hr) natural gas fired furnace with an Annual Fuel Utilization Efficiency (AFUE) rating exceeding the program requirements.

**DEFINITION OF BASELINE EQUIPMENT**

Time of Sale: The current Federal Standard for gas furnaces is an AFUE rating of 80%. The baseline will be adjusted when the Federal Standard is updated.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life. We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 20 years. For early replacement: Remaining life of existing equipment is assumed to be 6 years.

**DEEMED MEASURE COST**

Time of sale: The incremental installed cost (retail equipment cost plus installation cost) for this measure depends on efficiency as listed below:

<table>
<thead>
<tr>
<th>AFUE</th>
<th>Installed Cost</th>
<th>Incremental Installed Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>$2011</td>
<td>n/a</td>
</tr>
<tr>
<td>90%</td>
<td>$2641</td>
<td>$630</td>
</tr>
<tr>
<td>91%</td>
<td>$2727</td>
<td>$716</td>
</tr>
<tr>
<td>92%</td>
<td>$2813</td>
<td>$802</td>
</tr>
<tr>
<td>93%</td>
<td>$3025</td>
<td>$1014</td>
</tr>
<tr>
<td>94%</td>
<td>$3237</td>
<td>$1226</td>
</tr>
<tr>
<td>95%</td>
<td>$3449</td>
<td>$1438</td>
</tr>
<tr>
<td>96%</td>
<td>$3661</td>
<td>$1650</td>
</tr>
</tbody>
</table>

Early Replacement: The full installed cost is provided in the table above. The assumed deferred cost (after 6 years)

---


285: Assumed to be one third of effective useful life

286: Based on data from Table E.1.1 of Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor. ([http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf)). Where efficiency ratings are not provided, the values are interpolated from those that are. Note that ECM furnace fan cost (refer to other measure in TRM) has been deducted from the 93%-96% AFUE values to avoid double counting.
of replacing existing equipment with a new 90% baseline unit is assumed to be $2903\textsuperscript{287}. This cost should be discounted to present value using the nominal discount rate.

Verified Quality Installation: The additional design and installation work associated with verified quality installation has been estimated to take 1-2 hours (Tim Hanes, ESI). At $40/hr, VQI adds $60 to the installed cost.

**LOADSHAPE**

N/A

**COINCIDENCE FACTOR**

N/A

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Electrical energy savings from the more fan-efficient (typically using brushless permanent magnet (BPM) blower motor) should also be claimed, please refer to “Furnace Blower Motor” characterization for details.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

If the blower motor is also used for cooling, coincident peak demand savings should also be claimed, please refer to “Furnace Blower Motor” characterization for savings details.

**NATURAL GAS SAVINGS**

Time of Sale:

\[ \Delta \text{Therms} = \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \times \text{HF} \times \left( \frac{1}{\text{AFUE}(\text{base}) \times (1 - \text{Derating}(\text{base}))} - \frac{1}{\text{AFUE}(\text{eff}) \times (1 - \text{Derating}(\text{eff}))} \right) \]

Early replacement\textsuperscript{288}:

\[ \Delta \text{Therms for remaining life of existing unit (1st 6 years)}: \]

\[ = \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \times \text{HF} \times \left( \frac{1}{\text{AFUE}($exist$) \times (1 - \text{Derating}($exist$))} - \frac{1}{\text{AFUE}(\text{eff}) \times (1 - \text{Derating}(\text{eff}))} \right) \]

\[ \Delta \text{Therms for remaining measure life (next 14 years)}: \]

\[ = \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \times \text{HF} \times \left( \frac{1}{\text{AFUE}(\text{base}) \times (1 - \text{Derating}(\text{base}))} - \frac{1}{\text{AFUE}(\text{eff}) \times (1 - \text{Derating}(\text{eff}))} \right) \]

Where:

\[ \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \]

\textsuperscript{287} $2641$ inflated using 1.91% rate.

\textsuperscript{288} 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).
= Estimate of annual household heating load\(^{289}\) for gas furnace heated single-family homes. If location is unknown, assume the average below\(^{290}\).

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent\(^{291}\).

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas_Furnace_Heating_Load (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>873</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>834</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>714</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>551</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>561</td>
</tr>
<tr>
<td>Average</td>
<td>793</td>
</tr>
</tbody>
</table>

HF = Household factor, to adjust heating consumption for non-single-family households.

<table>
<thead>
<tr>
<th>Household Type</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>100%</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>65%(^{292})</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom(^{293})</td>
</tr>
</tbody>
</table>

AFUE\(_{\text{exist}}\) = Existing Furnace Annual Fuel Utilization Efficiency Rating

= Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4 AFUE\(^{%}\)\(^{294}\).

AFUE\(_{\text{base}}\) = Baseline Furnace Annual Fuel Utilization Efficiency Rating

= Dependent on program type as listed below\(^{295}\):

<table>
<thead>
<tr>
<th>Program Year</th>
<th>AFUE(_{\text{base}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>80%</td>
</tr>
<tr>
<td>Early Replacement(^{296})</td>
<td>90%</td>
</tr>
</tbody>
</table>

\(^{289}\) Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE).

\(^{290}\) Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

\(^{291}\) The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

\(^{292}\) Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes.

\(^{293}\) Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

\(^{294}\) Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

\(^{295}\) Though the Federal Minimum AFUE is 78%, there were only 50 models listed in the AHRI database at that level. At AFUE 79% the total rises to 308. There are 3,548 active furnace models listed with AFUE ratings between 78 and 80.

\(^{296}\) We estimate that the new baseline unit that could be purchased in the year the existing unit would have needed replacing is 90%.
AFUE\textsubscript{eff} = Efficient Furnace Annual Fuel Utilization Efficiency Rating
= Actual. If unknown, assume 95%\textsuperscript{297}
Derating\textsubscript{base} = Baseline furnace AFUE derating
= 6.4%\textsuperscript{298}
Derating\textsubscript{eff} = Efficient furnace AFUE derating
= 0% if verified quality installation is performed
= 6.4% if verified quality installation is not performed\textsuperscript{299}

Time of Sale:
For example, a 95% AFUE furnace purchased and installed with verified quality installation for an existing home near Rockford:
\[
\Delta \text{Therms} = 873 \times \left(\frac{1}{0.8 \times (1-6.4\%)} - \frac{1}{0.95 \times (1-0\%)}\right)
\]
= 247 therms
For example, a 95% AFUE furnace purchased and installed without verified quality installation for an existing home near Rockford:
\[
\Delta \text{Therms} = 873 \times \left(\frac{1}{0.8 \times (1-6.4\%)} - \frac{1}{0.95 \times (1-6.4\%)}\right)
\]
= 184 therms

Early Replacement:
For example, an existing functioning furnace with unknown efficiency is replaced with an 95% furnace using quality installation in Rockford:
\[
\Delta \text{Therms for remaining life of existing unit (1st 6 years)}:
= 873 \times \left(\frac{1}{0.644 \times (1-6.4\%)} - \frac{1}{0.95 \times (1-0\%)}\right)
\]
= 529 therms
\[
\Delta \text{Therms for remaining measure life (next 14 years)}:
= 873 \times \left(\frac{1}{0.9 \times (1-6.4\%)} - \frac{1}{0.95 \times (1-0\%)}\right)
\]
= 117 therms

\textbf{WATER IMPACT DESCRIPTIONS AND CALCULATION}
N/A

\textbf{DEEMED O&M COST ADJUSTMENT CALCULATION}
N/A

\textsuperscript{297} Minimum ENERGY STAR efficiency after 2.1.2012.
\textsuperscript{299} Ibid
MEASURE CODE: RS-HVC-GHEF-V07-180101

REVIEW DEADLINE: 1/1/2021
5.3.8 Ground Source Heat Pump

DESCRIPTION

This measure characterizes the installation of a Ground Source Heat Pump under the following scenarios:

a) New Construction:
   i. The installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below in a new home.
   ii. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

b) Time of Sale:
   i. The planned installation of a new residential sized Ground Source Heat Pump system meeting ENERGY STAR efficiency standards presented below to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   ii. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.

iii. Early Replacement/Retrofit:
   i. The early removal of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new high efficiency Ground Source Heat Pump system.
   ii. Note the baseline in this case is the existing equipment being replaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   iii. Additional DHW savings are calculated based upon the fuel and efficiency of the existing unit.
   iv. Early Replacement determination will be based on meeting the following conditions:
      • The existing unit is operational when replaced, or
      • The existing unit requires minor repairs, defined as costing less than $249:

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum repair cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>$276 per ton</td>
</tr>
<tr>
<td>Central Air Conditioner</td>
<td>$190 per ton</td>
</tr>
<tr>
<td>Boiler</td>
<td>$709</td>
</tr>
<tr>
<td>Furnace</td>
<td>$528</td>
</tr>
<tr>
<td>Ground Source Heat Pump</td>
<td>&lt;$249 per ton</td>
</tr>
</tbody>
</table>

   • All other conditions will be considered Time of Sale.

v. The Baseline efficiency of the existing unit replaced:
   • If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the “New Baseline” column below:

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum efficiency for Actual</th>
<th>New Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>10 SEER</td>
<td>14 SEER</td>
</tr>
</tbody>
</table>

300 The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.
If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
• If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

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

**Definition of Efficient Equipment**

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 below:

**ENERGY STAR Requirements (Effective January 1, 2012)**

<table>
<thead>
<tr>
<th>Product Type</th>
<th>Cooling EER</th>
<th>Heating COP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-to-air</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed Loop</td>
<td>17.1</td>
<td>3.6</td>
</tr>
<tr>
<td>Open Loop</td>
<td>21.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Water-to-Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed Loop</td>
<td>16.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Open Loop</td>
<td>20.1</td>
<td>3.5</td>
</tr>
<tr>
<td>DGX</td>
<td>16</td>
<td>3.6</td>
</tr>
</tbody>
</table>

**Definition of Baseline Equipment**

For these products, baseline equipment includes Air Conditioning, Space Heating and Water Heating.

**New Construction:**

To calculate savings with an electric baseline, 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 and a Federal Standard electric hot water heater.

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER. If a gas water heater, the Federal Standard baseline is calculated as follows:

\[
\]

\[
(0.8) \times (0.00078 \times \text{storage size in gallons}) + 0.615
\]

\[
= 0.675 - (0.0015 \times \text{storage size in gallons})
\]

For a 40-gallon storage water heater this would be 0.615 EF.

**Time of Sale:** The baseline for this measure is a new replacement unit of the same system type as the existing unit,

---


meeting the baselines provided below.

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>Efficiency Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHP</td>
<td>14 SEER, 11.8 EER, 8.2 HSPF</td>
</tr>
<tr>
<td>Gas Furnace</td>
<td>80% AFUE</td>
</tr>
<tr>
<td>Gas Boiler</td>
<td>82% AFUE</td>
</tr>
<tr>
<td>Central AC</td>
<td>13 SEER, 11 EER</td>
</tr>
</tbody>
</table>

Early replacement / Retrofit: The baseline for this measure is the efficiency of the existing heating, cooling and hot water equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change).

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 25 years. For early replacement, the remaining life of existing equipment is assumed to be 8 years.

**DEEMED MEASURE COST**

New Construction and Time of Sale: The actual installed cost of the Ground Source Heat Pump should be used (default of $3957 per ton), minus the assumed installation cost of the baseline equipment ($1381 per ton for ASHP or $2011 for a new baseline 80% AFUE furnace or $3543 for a new 82% AFUE boiler and $952 per ton for new baseline Central AC replacement).

Early Replacement: The full installation cost of the Ground Source Heat Pump should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and 1,047 per ton for new baseline Central AC replacement. This future cost should be discounted to present value using the nominal societal discount rate.

**LOADSHAPE**

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)

Loadshape R09 - Residential Electric Space Heat (if replacing electric heat with no cooling)

Loadshape R10 - Residential Electric Heating and Cooling (if replacing ASHP)

---

303 System life of indoor components as per DOE estimate http://energy.gov/energysaver/articles/geothermal-heat-pumps. The ground loop has a much longer life, but the compressor and other mechanical components are the same as an ASHP. http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

304 Assumed to be one third of effective useful life

305 Based on data provided in 'Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives'.


307 Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor (http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf). Where efficiency ratings are not provided, the values are interpolated from those that are.

308 Based on 3 ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator (http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CAC_CALC.XLS).

309 All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

310 The baseline for calculating electric savings is an Air Source Heat Pump.
Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
\text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)} \\
= 72\%^{311} \\
\text{CF}_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)} \\
= 46.6\%^{312}
\]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

New Construction and Time of Sale (non-fuel switch only):

\[
\Delta k\text{Wh} = [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \\
= [\text{FLHcool} \times \text{Capacity}_\text{cooling} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{Elecheat} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times (1/\text{HSPF}_{\text{base}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)]
\]

New Construction and Time of Sale (fuel switch only):

If measure is supported by gas utility only, \( \Delta k\text{WH} = 0 \)

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

\[
\Delta k\text{Wh} = [\text{Cooling savings}] + [\text{Heating savings from base ASHP to GSHP}] + [\text{DHW savings}] \\
= [\text{FLHcool} \times \text{Capacity}_\text{cooling} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{FLHheat} \times \text{Capacity}_\text{heating} \times (1/\text{HSPF}_{\text{ASHP}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)]
\]

Early replacement (non-fuel switch only)\(^{313}\):

\( \Delta k\text{WH} \) for remaining life of existing unit (1st 8 years):

\[^{311}\text{Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PYS coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PYS)’. }
\[^{312}\text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year. }
\[^{313}\text{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).}

\[ \Delta kWH = [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \]

\[ = [\text{FLHcool} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{exist}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{ElecHeat} \times \text{FLHheat} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{exist}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)] \]

\[ \Delta kWH \text{ for remaining life (next 17 years):} \]

\[ = [\text{FLHcool} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{ElecHeat} \times \text{FLHheat} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{base}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)] \]

**Early replacement - fuel switch only (see illustrative examples after Natural Gas section):**

If measure is supported by gas utility only, \( \Delta kWH = 0 \)

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

\[ \Delta kWh \text{ for remaining life of existing unit (1st 8 years):} \]

\[ = [\text{Cooling savings}] + [\text{Heating savings from base ASHP to GSHP}] + [\text{DHW savings}] \]

\[ = [\text{FLHcool} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{exist}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{FLHheat} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{ASHP}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)] \]

\[ \Delta kWH \text{ for remaining measure life (next 17 years):} \]

\[ = [\text{Cooling savings}] + [\text{Heating savings from base ASHP to GSHP}] + [\text{DHW savings}] \]

\[ = [\text{FLHcool} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{FLHheat} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{ASHP}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)] \]

Where:

- \( \text{FLHcool} \) = Full load cooling hours
  
  Dependent on location as below\textsuperscript{314}:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHcool Single Family</th>
<th>FLHcool Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td><strong>Weighted Average</strong>\textsuperscript{315}</td>
<td><strong>629</strong></td>
<td><strong>564</strong></td>
</tr>
</tbody>
</table>

- \( \text{Capacity}_{\text{cooling}} \) = Cooling Capacity of Ground Source Heat Pump (Btu/hr)
  
  = Actual (1 ton = 12,000Btu/hr)

- \( \text{SEER}_{\text{base}} \) = SEER Efficiency of new replacement baseline unit

\textsuperscript{314} Based on Full Load Hours from ENERGY STAR with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{315} Weighted based on number of occupied residential housing units in each zone.
### 5.3.8 Ground Source Heat Pump

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>SEERbase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>14\textsuperscript{316}</td>
</tr>
<tr>
<td>Central AC</td>
<td>13\textsuperscript{317}</td>
</tr>
<tr>
<td>No central cooling</td>
<td>13\textsuperscript{318}</td>
</tr>
</tbody>
</table>

SEER\textsubscript{exist} = SEER Efficiency of existing cooling unit

- Use actual SEER rating where it is possible to measure or reasonably estimate, if unknown assume default provided below:

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>SEER_exist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>9.12\textsuperscript{319}</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.60\textsuperscript{320}</td>
</tr>
<tr>
<td>No central cooling</td>
<td>13\textsuperscript{321}</td>
</tr>
</tbody>
</table>

SEER\textsubscript{ASHP} = SEER Efficiency of new baseline Air Source Heat Pump unit (for fuel switch)

- 14\textsuperscript{322}

EER\textsubscript{PL} = Part Load EER Efficiency of efficient GSHP unit\textsuperscript{323}

- Actual installed

ElecHeat = 1 if existing building is electrically heated

- 0 if existing building is not electrically heated

FLHheat = Full load heating hours

- Dependent on location as below\textsuperscript{324}:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,969</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,840</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,754</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,266</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,288</td>
</tr>
<tr>
<td>Weighted Average\textsuperscript{325}</td>
<td>1,821</td>
</tr>
</tbody>
</table>


\textsuperscript{318} Assumes that the decision to replace existing systems includes desire to add cooling.

\textsuperscript{319} Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

\textsuperscript{320} Ibid.

\textsuperscript{321} Assumes that the decision to replace existing systems includes desire to add cooling.


\textsuperscript{323} As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.

\textsuperscript{324} Heating EFLH based on ENERGY STAR EFLH for Rockford, Chicago, and Springfield and on NCDC/NOAA HDD for the other two cities. In all cases, the hours were adjusted based on average natural gas heating consumption in IL. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{325} Weighted based on number of occupied residential housing units in each zone.
\[ \text{Capacity}\_\text{heating} = \text{Heating Capacity of Ground Source Heat Pump (Btu/hr)} \]
\[ \quad = \text{Actual} \ (1 \text{ ton} = 12,000\text{Btu/hr}) \]
\[ \text{HSPF}_{\text{base}} = \text{Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)} \]

<table>
<thead>
<tr>
<th>Existing Heating System</th>
<th>HSPF_base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.2</td>
</tr>
<tr>
<td>Electric Resistance</td>
<td>3.41\text{[26]}</td>
</tr>
</tbody>
</table>

\[ \text{HSPF}\_\text{exist} = \text{Heating System Performance Factor of existing heating system (kBtu/kWh)} \]
\[ \quad = \text{Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:} \]

<table>
<thead>
<tr>
<th>Existing Heating System</th>
<th>HSPF_exist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>5.44</td>
</tr>
<tr>
<td>Electric Resistance</td>
<td>3.41</td>
</tr>
</tbody>
</table>

\[ \text{HSPF\_ASHP} = \text{Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)} \]
\[ \quad = 8.2\text{[27]} \]
\[ \text{COP}_{\text{PL}} = \text{Part Load Coefficient of Performance of efficient unit}\text{[28]}
\[ \quad = \text{ActualInstalled} \]
\[ 3.412 = \text{Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).} \]
\[ \text{ElecDHW} = 1 \text{ if existing DHW is electrically heated} \]
\[ \quad = 0 \text{ if existing DHW is not electrically heated} \]
\[ \%\text{DHWDisplaced} = \text{Percentage of total DHW load that the GSHP will provide} \]
\[ \quad = \text{Actual if known} \]
\[ \quad = \text{If unknown and if desuperheater installed assume 44\%}\text{[29]} \]
\[ \quad = 0\% \text{ if no desuperheater installed} \]
\[ \text{EF\_ELEC} = \text{Energy Factor (efficiency) of electric water heater} \]
\[ \quad = \text{Actual. If unknown or for new construction assume federal standard}\text{[30]} \]
\[ \text{For} \leq 55 \text{ gallons:} \quad 0.96 - (0.0003 \times \text{rated volume in gallons}) \]
\[ \text{For} > 55 \text{ gallons:} \quad 2.057 - (0.00113 \times \text{rated volume in gallons}) \]

\[ \text{[26]} \text{Electric resistance has a COP of 1.0 which equals} \ 1/0.293 = 3.41 \text{ HSPF.} \]
\[ \text{[28]} \text{As per conversations with David Buss territory manager for Connor Co, the SEER and COP ratings of an ASHP equate most appropriately with the part load EER and COP of a GSHP.} \]
\[ \text{[29]} \text{Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year (2/3 \times 2/3 = 44\%).} \]
\[ \text{[30]} \text{Based on input from Doug Dougherty, Geothermal Exchange Organization.} \]
GPD = Gallons Per Day of hot water use per person
    = 45.5 gallons hot water per day per household/2.59 people per household331
    = 17.6

Household = Average number of people per household

<table>
<thead>
<tr>
<th>Household Unit Type</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56332</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms333</td>
</tr>
</tbody>
</table>

365.25 = Days per year

γWater = Specific weight of water
    = 8.33 pounds per gallon

T_{OUT} = Tank temperature
    = 125°F

T_{IN} = Incoming water temperature from well or municipal system
    = 54°F334

1.0 = Heat Capacity of water (1 Btu/lb°F)

3412 = Conversion from Btu to kWh

333 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
334 US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL
http://www1.eere.energy.gov/buildings/building_america/analysis_spreadsheets.html
Illustrative Examples

New Construction using ASHP baseline:
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 Springfield:

\[ \Delta k\text{W} = \frac{\text{FLH}_{\text{cool}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000}{1000} + \frac{\text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{base}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000}{1000} + \frac{\text{ElecDHW} \times \%\text{DHW Displaced} \times ((1/\text{EF}_{\text{ELEC EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times y\text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)}{3412} \]

\[ \Delta k\text{W} = \frac{730 \times 36,000 \times (1/14 - 1/19)}{1000} + \frac{1754 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412))}{1000} + 1 \times 0.44 \times (1/0.945 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412 \]

\[ \Delta k\text{W} = 494 + 3494 + 1328 = 5316 \text{ kWh} \]

Early Replacement – non-fuel switch (see example after Natural gas section for Fuel switch):
For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 with desuperheater is installed in single family house in Springfield with a 50 gallon electric water heater replacing an existing working Air Source Heat Pump with unknown efficiency ratings:

\[ \Delta k\text{W} = \frac{730 \times 36,000 \times (1/9.12 - 1/19)}{1000} + \frac{1754 \times 36,000 \times (1/5.44 - 1/(4.4 \times 3.412))}{1000} + 0.44 \times 1 \times (1/0.945 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412 \]

\[ \Delta k\text{W} = 1498 + 7401 + 1328 = 10,227 \text{ kWh} \]

\[ \Delta k\text{W} = \frac{[730 \times 36,000 \times (1/14 - 1/28)]}{1000} + [1967 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412))]}{1000} + [0.44 \times 1 \times (1/0.945 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412] \]

\[ \Delta k\text{W} = 494 + 3494 + 1328 = 5316 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

New Construction and Time of Sale:

\[ \Delta kW = \frac{\text{Capacity}_{\text{cooling}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{PL}})}{1000} \times \text{CF} \]

Early replacement:

\[ \Delta kW = \frac{\text{Capacity}_{\text{cooling}} \times (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{PL}})}{1000} \times \text{CF} \]

\[ \Delta kW = \frac{\text{Capacity}_{\text{cooling}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{PL}})}{1000} \times \text{CF} \]

Where:

EERbase = EER Efficiency of new replacement unit
### Existing Cooling System

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>EER_base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>11.8 &lt;sup&gt;335&lt;/sup&gt;</td>
</tr>
<tr>
<td>Central AC</td>
<td>11 &lt;sup&gt;336&lt;/sup&gt;</td>
</tr>
<tr>
<td>No central cooling</td>
<td>11 &lt;sup&gt;337&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**EERexist**

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

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

\[
\text{EERexist} = (-0.02 \times \text{SEERexist}^2) + (1.12 \times \text{SEERexist})
\]

If SEER rating unavailable use:

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>EER_exist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.55</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.15 &lt;sup&gt;340&lt;/sup&gt;</td>
</tr>
<tr>
<td>No central cooling</td>
<td>11 &lt;sup&gt;341&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

**EER<sub>FL</sub>**

= Full Load EER Efficiency of ENERGY STAR GSHP unit

**CF<sub>SSP</sub>**

= Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 72%<sup>343</sup>

**CF<sub>PJM</sub>**

= PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%<sup>344</sup>

---

<sup>335</sup> The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.


<sup>337</sup> Assumes that the decision to replace existing systems includes desire to add cooling.


<sup>339</sup> Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

<sup>340</sup> Ibid.

<sup>341</sup> Assumes that the decision to replace existing systems includes desire to add cooling.

<sup>342</sup> 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.


<sup>344</sup> Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
New Construction or Time of Sale:
For example, a 3 ton unit with Full Load EER rating of 19:
\[
\Delta kW_{SSP} = \frac{(36,000 \times (1/11.8 - 1/19))}{1000} \times 0.72
\]
\[= 0.83 \text{ kW}\]
\[
\Delta kW_{PJM} = \frac{(36,000 \times (1/11 - 1/19))}{1000} \times 0.466
\]
\[= 0.54 \text{ kW}\]

Early Replacement:
For example, a 3 ton Full Load 19 EER replaces an existing working Air Source Heat Pump with unknown efficiency ratings in Marion:
\[
\Delta kW_{SSP} \text{ for remaining life of existing unit (1st 8 years)}:
\]
\[= \frac{(36,000 \times (1/8.55 - 1/19))}{1000} \times 0.72
\]
\[= 1.67 \text{ kW}\]
\[
\Delta kW_{SSP} \text{ for remaining measure life (next 17 years)}:
\]
\[= \frac{(36,000 \times (1/11.8 - 1/19))}{1000} \times 0.72
\]
\[= 0.83 \text{ kW}\]
\[
\Delta kW_{PJM} \text{ for remaining life of existing unit (1st 8 years)}:
\]
\[= \frac{(36,000 \times (1/8.55 - 1/19))}{1000} \times 0.466
\]
\[= 1.08 \text{ kW}\]
\[
\Delta kW_{PJM} \text{ for remaining measure life (next 17 years)}:
\]
\[= \frac{(36,000 \times (1/11.8 - 1/19))}{1000} \times 0.466
\]
\[= 0.54 \text{ kW}\]

**Natural Gas Savings**

New Construction and Time of Sale with baseline gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:
\[
\Delta \text{Therms} = [\text{Heating Savings}] + [\text{DHW Savings}]
\]
\[= [\text{Replaced gas consumption – therm equivalent of GSHP source kWh}] + [\text{DHW Savings}]
\]
\[= [(1 – \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbase}) - (\text{kWhToTherm} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times 1/(\text{COP}_{\text{PL}} \times 3.412)))/1000)] + [(1 – \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/100,000)]
\]

If measure is supported by electric utility only, \(\Delta\)Therms = 0

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):
\[
\Delta \text{Therms} = [\text{Heating Savings}] + [\text{DHW Savings}]
\]
\[= [\text{Replaced gas consumption – therm equivalent of base ASHP source kWh}] + [\text{DHW Savings}]
\]
\[= [(1 – \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbase}) - (\text{kWhToTherm} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times 1/(\text{COP}_{\text{PL}} \times 3.412)))/1000)] + [(1 – \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/100,000)]
\]
Ground Source Heat Pump

Early replacement for homes with existing gas heat and/or hot water:

If measure is supported by gas utility only, gas utility claim savings calculated below:

\[ \Delta \text{Therms for remaining life of existing unit (1st 8 years):} \]
\[ = [\text{Heating Savings}] + [\text{DHW Savings}] \]
\[ = [(1 - \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEexist}) - (\text{kWhtoTherm} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times 1/(\text{COP}_{\text{PL}} \times 3.412)/1000)) + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{OUT} - T_{IN}) \times 1.0) / 100,000]) \]

\[ \Delta \text{Therms for remaining measure life (next 17 years):} \]
\[ = [(1 - \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbaseER}) - (\text{kWhtoTherm} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times 1/(\text{HSPF}_{\text{ASHP}})/1000)) + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{OUT} - T_{IN}) \times 1.0) / 100,000]) \]

If measure is supported by electric utility only, \( \Delta \text{Therms} = 0 \)

If measure is supported by gas and electric utility, gas utility claim savings calculated below:

\[ \Delta \text{Therms for remaining life of existing unit (1st 8 years):} \]
\[ = [\text{Heating Savings}] + [\text{DHW Savings}] \]
\[ = [(1 - \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEexist}) - (\text{kWhtoTherm} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times 1/(\text{COP}_{\text{PL}} \times 3.412)/1000)) + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{OUT} - T_{IN}) \times 1.0) / 100,000]) \]

\[ \Delta \text{Therms for remaining measure life (next 17 years):} \]
\[ = [(1 - \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbaseER}) - (\text{kWhtoTherm} \times \text{FLHheat} \times \text{Capacity}_\text{heating} \times 1/(\text{HSPF}_{\text{ASHP}})/1000)) + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{OUT} - T_{IN}) \times 1.0) / 100,000]) \]

Where:

\[ \text{ElecHeat} = \begin{cases} 1 & \text{if existing building is electrically heated} \\ 0 & \text{if existing building is not electrically heated} \end{cases} \]

\[ \text{Gas}_\text{Heating}_\text{Load} = \text{Estimate of annual household heating load} \]

\[ = \begin{cases} \text{for gas furnace heated single-family homes. If location is unknown, assume the average below.} \\ \text{Actual if informed by site-specific load calculations, ACCA Manual J or equivalent} \end{cases} \]

---

345 Heating load is used to describe the household heating need, which is equal to \((\text{gas consumption} \times \text{AFUE})\)

346 The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.
<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas Heat Pump if Furnace (therms) 347</th>
<th>Gas Heat Pump if Boiler (therms) 348</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>873</td>
<td>1275</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>834</td>
<td>1218</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>714</td>
<td>1043</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>551</td>
<td>805</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>561</td>
<td>819</td>
</tr>
<tr>
<td>Average</td>
<td>793</td>
<td>1158</td>
</tr>
</tbody>
</table>

AFUEbase = Baseline Annual Fuel Utilization Efficiency Rating

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

kWhtoTherm = Converts source kWh to Therms

kWhtoTherm = \( \frac{H_{\text{grid}}}{100000} \)

AFUEexist = Existing Annual Fuel Utilization Efficiency Rating

AFUEexist = Use actual AFUE rating where it is possible to measure or reasonably estimate.

If unknown, assume 64.4% if furnace and 61.6% 349 if boiler.

AFUEbaseER = Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure

AFUEbaseER = 90%350 if furnace and 82% if boiler.

kWhtoTherm = Converts source kWh to Therms

kWhtoTherm = \( \frac{H_{\text{grid}}}{100000} \)

\( H_{\text{grid}} \) = Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest)351. Also include any line losses.

For systems operating more than 6,500 hrs per year:

- Non-Baseload RFC West: 9,811 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 10,511 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 10,038 Btu/kWh * (1 + Line Losses)
- All Fossil Average SERC Midwest: 10,364 Btu/kWh * (1 + Line Losses)

347 Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

348 Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor. Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

349 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

350 Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

3.412 = Converts COP to HSPF
EF_GAS_EXIST = Energy Factor (efficiency) of existing gas water heater
= Actual. If unknown assume federal standard\textsuperscript{352};
For \(\leq 55\) gallons: \(0.675 - (0.0015 \times \text{tank size})\)
For \(> 55\) gallons \(0.8012 - (0.00078 \times \text{tank size})\)
= If tank size unknown assume 40 gallons and EF_Baseline of 0.615

All other variables provided above

\textsuperscript{352} Minimum Federal Standard as of 4/1/2015:
Illustrative Examples [for illustrative purposes a Heat Rate of 10,000 Btu/kWh is used]

New construction using gas furnace and central AC baseline, supported by Gas utility only:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater is installed in place of a natural gas furnace and 3 ton Central AC unit:

\[
\Delta kWH = 0
\]

\[
\Delta \text{Therms} = \text{[Heating Savings]} + \text{[DHW Savings]}
\]

\[
= \text{[Replaced gas consumption – therm equivalent of GSHP source kWh]} + \text{[DHW Savings]}
\]

\[
= \left[ (1 - \text{ElecHeat}) \times \left( \frac{\text{Gas}_\text{Heating}_\text{Load}}{\text{AFUE}_{\text{base}}} \right) - (\text{kWh}_\text{toTherm} \times \text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times \frac{1}{(\text{COP}_{\text{PL}} \times 3.412) / 1000}) + \left( (1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times \left( \frac{1}{\text{EF}_{\text{GAS EXIST}}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 \right) / 100,000 \right) \right] + \left[ (1 - 0) \times (0.44 \times (1/0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1) / 100,000 \right]
\]

\[
= 472 + 70
\]

\[
= 542 \text{ therms}
\]

Early Replacement fuel switch, supported by gas and electric utility:

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings:

\[
\Delta kWH \text{ for remaining life of existing unit (1st 8 years)}:
\]

\[
= \text{[Cooling savings]} + \text{[Heating savings from base ASHP to GSHP]} + \text{[DHW savings]}
\]

\[
= \left[ (\text{FLH}_{\text{cool}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{exist}} - (1/\text{EER}_{\text{PL}})/1000)) + \left( \text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{ASHP}} - (1/\text{COP}_{\text{PL}} \times 3.412))/1000 \right) + \left( \text{ElecDHW} \times \%\text{DHWDisplaced} \times \left( (1/\text{EF}_{\text{ELEC}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 \right) / 3412 \right) \right]
\]

\[
= \left[ (730 \times 36,000 \times (1/0.86 - 1/19)) / 1000 \right] + \left[ \left( 1754 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412)) \right) / 1000 \right] + \left[ (0 \times 0.44 \times (1/(0.904) \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1)/3412 \right]
\]

\[
= 1673 + 3494 + 0
\]

\[
= 5167 \text{ kWh}
\]

Continued on next page.
Illustrative Example continued

\[ \Delta \text{kWh for remaining measure life (next 17 years):} \]
\[ = [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}] \]
\[ = \left\lbrack (\text{FLH}_\text{cool} \times \text{Capacity}_\text{cooling} \times \frac{(1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}})/1000)}{1000}\right\rbrack + \left\lbrack (\text{FLH}_\text{heat} \times \text{Capacity}_\text{heating} \times \frac{(1/\text{HSPF}_{\text{ASHP}} - (1/\text{COP}_{\text{PL}} \times 3.412))/1000}{1000}\right\rbrack + \left\lbrack (\text{ElecDHW} \times \% \text{DHWDisplaced} \times \left\lbrack \left(\frac{(1/\text{EF}_{\text{ELEC}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma \text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0}{3412}\right) \right\rbrack\right\rbrack \]
\[ = \left\lbrack (730 \times 36,000 \times (1/13 - 1/19))/1000\right\rbrack + \left\lbrack (1754 \times 36,000 \times (1/8.2 - 1/ (4.4 \times 3.412))/1000\right\rbrack + \left\lbrack (0 \times 0.44 \times (1/0.904) \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412\right\rbrack \]
\[ = 638 + 3494 + 0 \]
\[ = 4132 \text{ kWh} \]

\[ \Delta \text{Therms for remaining life of existing unit (1st 8 years):} \]
\[ = [\text{Heating Savings}] + [\text{DHW Savings}] \]
\[ = [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] + [\text{DHW Savings}] \]
\[ = \left\lbrack ((1 - \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{exist}})) - (\text{kWh}_{\text{ToTherm}} \times \text{FLH}_{\text{heat}} \times \text{Capacity}_\text{heating} \times (1/\text{HSPF}_{\text{ASHP}})/1000)} + \left\lbrack ((1 - \text{ElecDHW}) \times \% \text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma \text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/100,000\right\rbrack \right\rbrack \]
\[ = \left\lbrack (1-0) \times ((714/0.644) - (10000/100000 \times 1754 \times 36,000 \times 1/8.2)/1000)\right\rbrack + \left\lbrack (1 - 0) \times (0.44 \times (1/0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/100,000\right\rbrack \]
\[ = 339 + 70 \]
\[ = 408 \text{ therms} \]

\[ \Delta \text{Therms for remaining measure life (next 17 years):} \]
\[ = \left\lbrack ((1 - \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{baseER}})) - (\text{kWh}_{\text{ToTherm}} \times \text{FLH}_{\text{heat}} \times \text{Capacity}_\text{heating} \times (1/\text{HSPF}_{\text{ASHP}})/1000)} + \left\lbrack ((1 - \text{ElecDHW}) \times \% \text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS EXIST}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma \text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/100,000\right\rbrack \right\rbrack \]
\[ = \left\lbrack (1-0) \times ((714/0.9) - (10000/100000 \times 1754 \times 36,000 \times 1/8.2)/1000)\right\rbrack + \left\lbrack (1 - 0) \times (0.44 \times (1/0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/100,000\right\rbrack \]
\[ = 23 + 70 \]
\[ = 93 \text{ therms} \]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING**

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch GSHP projects per Section 16-111.5B, changes in
site energy use at the customer’s meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the “Electric Energy Savings” and “Natural Gas Savings” sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

\[
\Delta \text{Therms} = [\text{Heating Consumption Replaced}] + [\text{DHW Savings if gas}]
\]
\[
= [(1 - \text{ElecHeat}) * ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbase})] + [(1 - \text{ElecDHW}) * \%\text{DHWDisplaced} 
\times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000)]
\]

\[
\Delta \text{kWh} = - [\text{GSHP heating consumption}] + [\text{Cooling savings}] + [\text{DHW savings if electric}]
\]
\[
= - [(\text{FLHheat} * \text{Capacity}_\text{heating} * (1/\text{COP}_{\text{PL}} \times 3.412)/1000] + [(\text{FLHcool} * \text{Capacity}_\text{cooling} * (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [(\text{ElecDHW} * \%\text{DHWDisplaced} 
\times (1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)]
\]

**Illustrative Example of Cost Effectiveness Inputs for Fuel Switching**

For example, a 3 ton unit with Part Load EER rating of 19 and Part Load COP of 4.4 in single family house in Springfield with a 40 gallon gas water heater replaces an existing working natural gas furnace and 3 ton Central AC unit with unknown efficiency ratings. [Note the calculation provides the annual savings for the first 8 years of the measure life, an additional calculation (not shown) would be required to calculated the annual savings for the remaining life (years 9-25)]:

\[
\Delta \text{Therms} = [(1 - \text{ElecHeat}) * ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEexist})] + [(1 - \text{ElecDHW}) * \%\text{DHWDisplaced} 
\times (1/\text{EF}_{\text{GAS EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 100,000)]
\]
\[
= [(1-0) * (714/0.644)] + [((1 - 0) * 0.44 * (1/ 0.615 * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1) / 100,000)]
\]
\[
= 1109 + 70
\]
\[
= 1179 \text{ therms}
\]

\[
\Delta \text{kWh} = - [(\text{FLHheat} * \text{Capacity}_\text{heating} * (1/\text{COP}_{\text{PL}} \times 3.412)/1000] + [(\text{FLHcool} * \text{Capacity}_\text{cooling} * (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [(\text{ElecDHW} * \%\text{DHWDisplaced} 
\times (1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) * 1.0) / 3412)]
\]
\[
= - [(1754 * 36,000 * (1/4.4 * 3.412))/ 1000] + [(730 * 36,000 * (1/8.6 - 1/19))/ 1000] + [0 * 0.44 * ((1/0.904) * 17.6 * 2.56 *365.25 * 8.33 * (125-54) * 1)/3412]
\]
\[
= -4206 + 1673 + 0
\]
\[
= -2533 \text{ kWh}
\]

\[353\] Note AFUEbase in the algorithm should be replaced with AFUEexist for early replacement measures.

\[354\] Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.
MEASURE CODE: RS-HVC-GSHP-V07-180101

REVIEW DEADLINE: 1/1/2021
5.3.9 High Efficiency Bathroom Exhaust Fan

**DESCRIPTION**

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at a sound level of less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

New efficient (average CFM/watt of 8.3) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2.

**DEFINITION OF BASELINE EQUIPMENT**

New standard efficiency (average CFM/Watt of 3.1) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 19 years.

**DEEMED MEASURE COST**

Incremental cost per installed fan is $43.50 for quiet, efficient fans.

**LOADSHAPE**

Loadshape R11 - Residential Ventilation

**COINCIDENCE FACTOR**

The summer Peak Coincidence Factor is assumed to be 100% because the fan runs continuously.

---

355 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.

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

357 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.

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

359 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.

360 VEIC analysis using cost data collected from wholesale vendor: http://www.westsidewholesale.com/.
CALCULATION OF SAVINGS

**ELECTRIC ENERGY SAVINGS**

\[ \Delta k\text{Wh} = \left( \text{CFM} \times \frac{1}{\eta_{\text{BASELINE}}} - \frac{1}{\eta_{\text{EFFICIENT}}} \right) / 1000 \times \text{Hours} \]

Where:

- **CFM** = Nominal Capacity of the exhaust fan
  = 50 CFM

- **\( \eta_{\text{BASELINE}} \)** = Average efficacy for baseline fan
  = 3.1 CFM/Watt

- **\( \eta_{\text{EFFICIENT}} \)** = Average efficacy for efficient fan
  = 8.3 CFM/Watt

- **Hours** = assumed annual run hours,
  = 8766 for continuous ventilation.

\[ \Delta k\text{Wh} = \left( 50 \times \frac{1}{3.1} - \frac{1}{8.3} \right) / 1000 \times 8766 \]

\[ \Delta k\text{Wh} = 88.6 \text{kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \left( \text{CFM} \times \frac{1}{\eta_{\text{BASELINE}}} - \frac{1}{\eta_{\text{EFFICIENT}}} \right) / 1000 \times \text{CF} \]

Where:

- **CF** = Summer Peak Coincidence Factor
  = 1.0 (continuous operation)

Other variables as defined above

\[ \Delta kW = \left( 50 \times \frac{1}{3.1} - \frac{1}{8.3} \right) / 1000 \times 1.0 \]

\[ \Delta kW = 0.0101 \text{kW} \]

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

---

361 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.

362 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.

363 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.
DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-HVC-BAFA-V01-120601

REVIEW DEADLINE: 1/1/2019
5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

**DESCRIPTION**

This measure involves the measurement of refrigerant charge levels and airflow over the central air conditioning or heat pump unit coil, correction of any problems found and post-treatment re-measurement. Measurements must be performed with standard industry tools and the results tracked by the efficiency program.

Savings from this measure are developed using a reputable Wisconsin study. It is recommended that future evaluation be conducted in Illinois to generate a more locally appropriate characterization.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

N/A

**DEFINITION OF BASELINE EQUIPMENT**

This measure assumes that the existing unit being maintained is either a residential central air conditioning unit or an air source heat pump that has not been serviced for at least 3 years.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 2 years.

**DEEMED MEASURE COST**

If the implementation mechanism involves delivering and paying for the tune up service, the actual cost should be used. If however the customer is provided a rebate and the program relies on private contractors performing the work, the measure cost should be assumed to be $175.

**LOADSHAPE**

Loadshape R08 - Residential Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
\begin{align*}
CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \\
&= 68\%^{366} \\
CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \\
&= 72\%^{367}
\end{align*}
\]

---

364 Based on VEIC professional judgment.
365 Based on personal communication with HVAC efficiency program consultant Buck Taylor or Roltay Inc., 6/21/10, who estimated the cost of tune up at $125 to $225, depending on the market and the implementation details.
366 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
367 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PYS)’.
\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[ = 46.6\%^{368} \]

Algorithm

**Calculation of Savings**

**Electric Energy Savings**

\[
\Delta \text{kWh}_{\text{Central AC}} = (\text{FLHcool} * \text{Capacity}_{\text{cooling}} * (1/\text{SEER}_{\text{CAC}}))/1000 * \text{MFe}
\]
\[
\Delta \text{kWh}_{\text{Air Source Heat Pump}} = ((\text{FLHcool} * \text{Capacity}_{\text{cooling}} * (1/\text{SEER}_{\text{ASHP}}))/1000 * \text{MFe}) + (\text{FLHheat} * \text{Capacity}_{\text{heating}} * (1/\text{HSPF}_{\text{ASHP}}))/1000 * \text{MFe}
\]

Where:

- \text{FLHcool} = Full load cooling hours
  - Dependent on location as below:
    - Climate Zone (City based upon)
    - \text{FLHcool} (Single Family)
    - \text{FLHcool} (Multifamily)
    - 1 (Rockford) 512 467
    - 2 (Chicago) 570 506
    - 3 (Springfield) 730 663
    - 4 (Belleville) 1,035 940
    - 5 (Marion) 903 820
    - Weighted Average\(^{370}\) 629 564

- \text{Capacity}_{\text{cooling}} = \text{Cooling capacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)}
  - = Actual

- \text{SEER}_{\text{CAC}} = \text{SEER Efficiency of existing central air conditioning unit receiving maintenance}
  - = Actual. If unknown assume 10 SEER \(^{371}\)

- \text{MFe} = \text{Maintenance energy savings factor}
  - = 0.05\(^{372}\)

- \text{SEER}_{\text{ASHP}} = \text{SEER Efficiency of existing air source heat pump unit receiving maintenance}
  - = Actual. If unknown assume 10 SEER \(^{373}\)

\(^{368}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\(^{369}\) Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\(^{370}\) Weighted based on number of occupied residential housing units in each zone.

\(^{371}\) Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.

\(^{372}\) Energy Center of Wisconsin, May 2008; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.”

\(^{373}\) Use actual SEER rating where it is possible to measure or reasonably estimate. Unknown default of 10 SEER is a VEIC estimate of existing unit efficiency, based on minimum federal standard between the years of 1992 and 2006.
HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

\[ \text{FLHheat} = \text{Full load heating hours} \]

Dependent on location:\textsuperscript{374}

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>2208</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>2064</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1967</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1420</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1445</td>
</tr>
<tr>
<td>Weighted Average\textsuperscript{375}</td>
<td>1821</td>
</tr>
</tbody>
</table>

\[ \text{Capacity}_{\text{heating}} = \text{Heating capacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)} \]

\[ \text{HSPF}_{\text{ASHP}} = \text{Heating Season Performance Factor of existing air source heat pump unit receiving maintenance} \]

\[ = \text{Actual. If unknown assume 6.8 HSPF} \textsuperscript{376} \]

For example, maintenance of a 3-ton, SEER 10 air conditioning unit in a single family house in Springfield:

\[ \Delta \text{kWh}_{\text{CAC}} = \frac{(730 \times 36,000 \times (1/10))/1000 \times 0.05}{\text{131 kWh}} \]

For example, maintenance of a 3-ton, SEER 10, HSPF 6.8 air source heat pump unit in a single family house in Springfield:

\[ \Delta \text{kWh}_{\text{ASHP}} = \left(\frac{(730 \times 36,000 \times (1/10))/1000 \times 0.05}{1967 \times 36,000 \times (1/6.8)/1000 \times 0.05}\right) \]

\[ = 652 \text{kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta \text{kW} = \text{Capacity}_{\text{cooling}} \times (1/\text{EER})/1000 \times \text{Mfd} \times \text{CF} \]

Where:

\[ \text{EER} = \text{EER Efficiency of existing unit receiving maintenance in Btu/H/Watts} \]

\[ = \text{Calculate using Actual SEER} \]

\[ = -0.02 \times \text{SEER}^2 + 1.12 \times \text{SEER} \textsuperscript{377} \]

\textsuperscript{374} Full load heating hours for heat pumps are provided for Rockford, Chicago and Springfield in the Energy Star Calculator. Estimates for the other locations were calculated based on the FLH to Heating Degree Day (from NCDC) ratio. VEIC consider Energy Star estimates to be high due to oversizing not being adequately addressed. Using average Illinois billing data (from http://www.icc.illinois.gov/ags/consumereducation.aspx) VEIC estimated the average gas heating load and used this to estimate the average home heating output (using 83% average gas heat efficiency). Dividing this by a typical 36,000 Btu/hr ASHP gives an estimate of average ASHP FLH_heat of 1821 hours. We used the ratio of this value to the average of the locations using the Energy Star data (1994 hours) to scale down the Energy Star estimates. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{375} Weighted based on number of occupied residential housing units in each zone.

\textsuperscript{376} Use actual HSPF rating where it is possible to measure or reasonably estimate. Unknown default of 6.8 HSPF is a VEIC estimate based on minimum Federal Standard between 1992 and 2006.

MFd = Maintenance demand savings factor
= 0.02 \textsuperscript{378}

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
= 68\% \textsuperscript{379}

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)
= 72\% \textsuperscript{380}

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Central A/C and Heat Pumps (average during peak period)
= 46.6\% \textsuperscript{381}

For example, maintenance of 3-ton, SEER 10 (equals EER 9.2) CAC unit:

$\Delta kW_{SSP} = 36,000 \times 1/(9.2)/1000 \times 0.02 \times 0.68$
= 0.0532 kW

$\Delta kW_{PJM} = 36,000 \times 1/(9.2)/1000 \times 0.02 \times 0.466$
= 0.0365 kW

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Conservatively not included.

**MEASURE CODE: RS-HVC-TUNE-V03-160601**

**REVIEW DEADLINE: 1/1/2021**
5.3.11 Programmable Thermostats

DESCRIPTION
This measure characterizes the household energy savings from the installation of a new or reprogramming of an existing Programmable Thermostat for reduced heating energy consumption through temperature set-back during unoccupied or reduced demand times. Because a literature review was not conclusive in providing a defensible source of prescriptive cooling savings from programmable thermostats, cooling savings from programmable thermostats are assumed to be zero for this version of the measure. It is not appropriate to assume a similar pattern of savings from setting a thermostat down during the heating season and up during the cooling season. Note that the EPA’s EnergyStar program is developing a new specification for this project category, and if/when evaluation results demonstrate consistent cooling savings, subsequent versions of this measure will revisit this assumption. Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple programmable thermostats per home does not accrue additional savings. This measure was developed to be applicable to the following program types: TOS, NC, RF, DI.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
The criteria for this measure are established by replacement of a manual-only temperature control, with one that has the capability to adjust temperature setpoints according to a schedule without manual intervention. This category of equipment is broad and rapidly advancing in regards to the capability, and usability of the controls and their sophistication in setpoint adjustment and information display, but for the purposes of this characterization, eligibility is perhaps most simply defined by what it isn’t: a manual only temperature control.

For the thermostat reprogramming measure, the auditor consults with the homeowner to determine an appropriate set back schedule, reprograms the thermostat and educates the homeowner on its appropriate use.

DEFINITION OF BASELINE EQUIPMENT
For new thermostats the baseline is a non-programmable thermostat requiring manual intervention to change temperature setpoint.

For the purpose of thermostat reprogramming, an existing programmable thermostat that an auditor determines is being used in override mode or otherwise effectively being operated like a manual thermostat.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life of a programmable thermostat is assumed to be 10 years based upon equipment life only. For the purposes of claiming savings for a new programmable thermostat, this is reduced by a 50% persistence factor to give final measures life of 5 years. For reprogramming, this is reduced further to give a measure life of 2 years.

DEEMED MEASURE COST
Actual material and labor costs should be used if the implementation method allows. If unknown (e.g. through a

---

382 The EnergyStar program discontinued its support for this measure category effective 12/31/09, and is presently developing a new specification for ‘Residential Climate Controls’.
383 Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007
384 Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a large scale but only 2-year study of the energy impacts of programmable thermostats, the longer term impacts should be assessed.
The capital cost for the new installation measure is assumed to be $30,385. The cost for reprogramming is assumed to be $10 to account for the auditors time to reprogram and educate the homeowner.

**LOADSHAPE**

Loadshape R09 - Residential Electric Space Heat

**COINCIDENCE FACTOR**

N/A due to no savings attributable to cooling during the summer peak period.

### Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta \text{kWh}^{386} = \%\text{ElectricHeat} \times \text{Elec\_Heating\_Consumption} \times \text{Heating\_Reduction} \times \text{HF} \times \text{Eff\_ISR} + \left( \Delta \text{Therms} \times F_e \times 29.3 \right)
\]

Where:

\[
\%\text{ElectricHeat} = \text{Percentage of heating savings assumed to be electric}
\]

<table>
<thead>
<tr>
<th>Heating fuel</th>
<th>%ElectricHeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>6.5%(^{387})</td>
</tr>
</tbody>
</table>

\[
\text{Elec\_Heating\_Consumption} = \text{Estimate of annual household heating consumption for electrically heated single-family homes}^{388}. \text{If location and heating type is unknown, assume 15,678 kWh}^{389}
\]

---

385 Market prices vary significantly in this category, generally increasing with thermostat capability and sophistication. The basic functions required by this measure's eligibility criteria are available on units readily available in the market for the listed price.

386 Note the second part of the algorithm relates to furnace fan savings if the heating system is Natural Gas.

387 Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat (consistent with Potential Study results from the state). Average value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

388 Values in table are based on converting an average household heating load (834 therms) for Chicago based on ‘Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03413) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (see ‘Household Heating Load Summary Calculations_11062013.xls’). Finally these values were adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

389 Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois.
### Climate Zone (City based upon) | Electric Resistance Elec_Heating_Consumption (kWh) | Electric Heat Pump Elec_Heating_Consumption (kWh) |
--- | --- | --- |
1 (Rockford) | 21,741 | 12,789 |
2 (Chicago) | 20,771 | 12,218 |
3 (Springfield) | 17,789 | 10,464 |
4 (Belleville) | 13,722 | 8,072 |
5 (Marion) | 13,966 | 8,215 |
Average | 19,743 | 11,613 |

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to programmable thermostat

= 6.2%\(^{390}\)

HF = Household factor, to adjust heating consumption for non-single-family households.

<table>
<thead>
<tr>
<th>Household Type</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>100%</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>65%(^{391})</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom(^{392})</td>
</tr>
</tbody>
</table>

Eff_ISR = Effective In-Service Rate, the percentage of thermostats installed and programmed effectively

<table>
<thead>
<tr>
<th>Program Delivery</th>
<th>Eff_ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install</td>
<td>100%</td>
</tr>
<tr>
<td>Other, or unknown</td>
<td>56%(^{393})</td>
</tr>
</tbody>
</table>

\(\Delta\)Therms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

\(F_e\) = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%\(^{394}\)

\(^{390}\) The savings from programmable thermostats are highly susceptible to many factors best addressed, so far for this category, by a study that controlled for the most significant issues with a very large sample size. To the extent that the treatment group is representative of the program participants for IL, this value is suitable. Higher and lower values would be justified based upon clear dissimilarities due to program and product attributes. Future evaluation work should assess program specific impacts associated with penetration rates, baseline levels, persistence, and other factors which this value represents.

\(^{391}\) Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes.

\(^{392}\) Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.


\(^{394}\) \(F_e\) is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, “50% greater than the Energy Star version 3 criteria for 2% \(F_e\). See
For example, a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield:

\[
\Delta \text{kWh} = 1 \times 17,789 \times 0.062 \times 100\% \times 100\% + (0 \times 0.0314 \times 29.3) \\
= 1,103 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A due to no savings from cooling during the summer peak period.

**NATURAL GAS ENERGY SAVINGS**

\[
\Delta \text{Therms} = \%\text{FossilHeat} \times \text{Gas\_Heating\_Consumption} \times \text{Heating\_Reduction} \times \text{HF} \times \text{Eff\_ISR}
\]

Where:

<table>
<thead>
<tr>
<th>Heating fuel</th>
<th>%FossilHeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>93.5%(^{395})</td>
</tr>
</tbody>
</table>

\[
\text{Gas\_Heating\_Consumption} = \text{Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below}^{396}.
\]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas_Heating_Consumption (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,052</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,005</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>861</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>664</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>676</td>
</tr>
<tr>
<td>Average</td>
<td>955</td>
</tr>
</tbody>
</table>

\(^{395}\) Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat. Data from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

\(^{396}\) Values are based on adjusting the average household heating load (834 therms) for Chicago based on ‘Table E-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1, Research Report: Furnace Metering Study’, divided by standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83) to give 1005 therms. This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

“Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.
For example, a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

\[ \Delta \text{Therms} = 1.0 \times 1005 \times 0.062 \times 100\% \times 100\% \]

\[ = 62.3 \text{ therms} \]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-HVC-PROG-V04-180101

**REVIEW DEADLINE:** 1/1/2021
5.3.12 Ductless Heat Pumps

DESCRIPTION

This measure is designed to calculate electric savings for the installation of a ductless mini-split heat pump (DMSHP). DMSHPs save energy in heating mode because they provide heat more efficiently than electric resistance heat and central ASHP systems. Additionally, DMSHPs use less fan energy to move heat and don’t incur heat loss through a duct distribution system.

For cooling, the proposed savings calculations are aligned with those of typical replacement systems. DMSHPs save energy in cooling mode because they provide cooling capacity more efficiently than other types of unitary cooling equipment. A DMSHP installed in a home with a central ASHP system will save energy by offsetting some of the cooling energy of the ASHP. In order for this measure to apply, the control strategy for the heat pump is assumed to be chosen to maximize savings per installer recommendation.\(^ {397}\)

This measure characterizes the following scenarios:

d) New Construction:
   a. The installation of a new DMSHP meeting efficiency standards required by the program in a new home.
   b. Note the baseline in this case should be determined via EM&V and the algorithms are provided to allow savings to be calculated from any baseline condition.

e) Time of Sale:
   a. The planned installation of a new DMSHP meeting efficiency standards required by the program to replace an existing system(s) that does not meet the criteria for early replacement described in section c below.
   b. Note the baseline in this case is an equivalent replacement system to that which exists currently in the home. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.

f) Early Replacement/Retrofit:
   a. The early removal or displacement of functioning either electric or gas space heating and/or cooling systems from service, prior to the natural end of life, and replacement with a new DMSHP.
   b. Note the baseline in this case is the existing equipment being replaced/displaced. The calculation of savings is dependent on whether an incentive for the installation has been provided by both a gas and electric utility, just an electric utility or just a gas utility.
   c. Early Replacement determination will be based on meeting the following conditions:
      • The existing unit is operational when replaced/displaced, or
      • The existing unit requires minor repairs, defined as costing less than:\(^ {398}\):

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum repair cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>$276 per ton</td>
</tr>
<tr>
<td>Central Air Conditioner</td>
<td>$190 per ton</td>
</tr>
</tbody>
</table>

\(^ {397}\) The whole purpose of installing ductless heat pumps is to conserve energy, so the installer can be assumed to be capable of recommending an appropriate controls strategy. For most applications, the heating setpoint for the ductless heat pump should be at least 2F higher than any remaining existing system and the cooling setpoint for the ductless heat pump should be at least 2F cooler than the existing system (this should apply to all periods of a programmable schedule, if applicable). This helps ensure that the ductless heat pump will be used to meet as much of the load as possible before the existing system operates to meet the remaining load. Ideally, the new ductless heat pump controls should be set to the current comfort settings, while the existing system setpoints should be adjusted down (heating) and up (cooling) to capture savings.

\(^ {398}\) The Technical Advisory Committee agreed that if the cost of repair is less than 20% of the new baseline replacement cost it can be considered early replacement.
Existing System | Maximum repair cost
---|---
Boiler | $709
Furnace | $528
Ground Source Heat Pump | <$249 per ton

- All other conditions will be considered Time of Sale.

d. The Baseline efficiency of the existing unit replaced:
  - If the efficiency of the existing unit is less than the maximum shown below, the Baseline efficiency is the actual efficiency value of the unit replaced. If the efficiency is greater than the maximum, the Baseline efficiency is shown in the “New Baseline” column below:

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum efficiency for Actual</th>
<th>New Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>10 SEER</td>
<td>14 SEER</td>
</tr>
<tr>
<td>Central Air Conditioner</td>
<td>10 SEER</td>
<td>13 SEER</td>
</tr>
<tr>
<td>Boiler</td>
<td>75% AFUE</td>
<td>82% AFUE</td>
</tr>
<tr>
<td>Furnace</td>
<td>75% AFUE</td>
<td>80% AFUE</td>
</tr>
<tr>
<td>Ground Source Heat Pump</td>
<td>10 SEER</td>
<td>13 SEER</td>
</tr>
</tbody>
</table>

- If the efficiency of the existing unit is unknown, use assumptions in variable list below (SEER, HSPF or AFUE exist).
- If the operational status or repair cost of the existing unit is unknown use time of sale assumptions.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, the new equipment must be a high-efficiency, variable-capacity (typically “inverter-driven” DC motor) ductless heat pump system that exceeds the program minimum efficiency requirements.

**DEFINITION OF BASELINE EQUIPMENT**

For these products, baseline equipment includes Air Conditioning and Space Heating:

New Construction:

To calculate savings with an electric baseline, 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.\(^{400}\)

To calculate savings with a furnace/central AC baseline, the baseline equipment is assumed to be an 80% AFUE Furnace and central AC meeting the Federal Standard efficiency level; 13 SEER, 11 EER.

Time of Sale: The baseline for this measure is a new replacement unit of the same system type as the existing unit, meeting the baselines provided below.

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>Efficiency Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHP</td>
<td>14 SEER, 11.8 EER, 8.2 HSPF</td>
</tr>
</tbody>
</table>

\(^{399}\) Based on relevant Federal Standards.

\(^{400}\) The Federal Standard does not include an EER requirement, so it is approximated with this formula: \((-0.02 \cdot \text{SEER}) + (1.12 \cdot \text{SEER})\) Wassmer, M. (2003). ‘A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations’ Masters Thesis, University of Colorado at Boulder.
Early replacement / Retrofit: The baseline for this measure is the efficiency of the *existing* heating and cooling equipment for the assumed remaining useful life of the existing unit and a new baseline heating and cooling system for the remainder of the measure life (as provided in table above except for Gas Furnace where new baseline assumption is 90% due to pending standard change). Note that in order to claim cooling savings, there must be an existing air conditioning system.

For multifamily buildings, each residence must have existing individual heating equipment. Multifamily residences with central heating do not qualify for this characterization.

### DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 18 years\(^\text{401}\).

For early replacement, the remaining life of existing equipment is assumed to be 6 years\(^\text{402}\).

### DEEMED MEASURE COST

New Construction and Time of Sale: The actual installed cost of the DMSHP should be used (defaults are provided below), minus the assumed installation cost of the baseline equipment ($1,381 per ton for ASHP\(^\text{403}\) or $2,011 for a new baseline 80% AFUE furnace or $3,543 for a new 82% AFUE boiler\(^\text{404}\) and $952 per ton\(^\text{405}\) for new baseline Central AC replacement).

<table>
<thead>
<tr>
<th>Unit Size</th>
<th>Full Install Cost(^\text{406})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Ton</td>
<td>$3,000</td>
</tr>
<tr>
<td>1.5-Ton</td>
<td>$3,750</td>
</tr>
<tr>
<td>2-Ton</td>
<td>$4,500</td>
</tr>
<tr>
<td>2.5 – Ton</td>
<td>$5,313</td>
</tr>
<tr>
<td>3-Ton</td>
<td>$6,188</td>
</tr>
</tbody>
</table>

Early Replacement/retrofit (replacing existing equipment): The full installation cost of the DMSHP should be used (default provided above). The assumed deferred cost (after 8 years) of replacing existing equipment with a new baseline unit is assumed to be $1,518 per ton for a new baseline Air Source Heat Pump, or $2,903 for a new baseline 90% AFUE furnace or $4,045 for a new 82% AFUE boiler and $1,047 per ton for new baseline Central AC replacement\(^\text{407}\). This future cost should be discounted to present value using the nominal societal discount rate.

Where the DMSHP is a supplemental HVAC system, the full installation cost of the DMSHP should be used (default

---


\(^{402}\) Assumed to be one third of effective useful life


\(^{404}\) Furnace and boiler costs are based on data provided in Appendix E of the Appliance Standards Technical Support Documents including equipment cost and installation labor ([http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/fb_fr_tsd/appendix_e.pdf)). Where efficiency ratings are not provided, the values are interpolated from those that are.

\(^{405}\) Based on 3 Ton initial cost estimate for a conventional unit from ENERGY STAR Central AC calculator ([http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CAC.xls)).

\(^{407}\) All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.
provided above) without a deferred replacement cost.

**LOADSHAPE**

Loadshape R10 - Residential Electric Heating and Cooling (if replacing gas heat and central AC)
Loadshape R09 - Residential Electric Space Heat (if replacing electric heat with no cooling)
Loadshape R10 - Residential Electric Heating and Cooling (if replacing ASHP)

Note for purpose of cost effectiveness screening a fuel switch scenario, the heating kWh increase and cooling kWh decrease should be calculated separately such that the appropriate loadshape (i.e. Loadshape R09 - Residential Electric Space Heat and Loadshape R08 – Residential Cooling respectively) can be applied.

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in four different ways below. The first two relate to the use of DMSHP to supplement existing cooling or provide limited zonal cooling, the second two relate to use of the DMSHP to provide whole house cooling. In each pair, the first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market. Both values provided are based on metering data for 40 DMSHPs in Ameren Illinois service territory.

For supplemental or limited zonal cooling:

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)} \]
\[ = 43.1\% \]  

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)} \]
\[ = 28.0\% \]

For whole house cooling:

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)} \]
\[ = 72\% \]

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)} \]
\[ = 46.6\% \]

---

408 The baseline for calculating electric savings is an Air Source Heat Pump.

409 All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015

410 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

411 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

412 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

413 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
**Algorithms**

**Calculation of Savings**

**Electric Energy Savings**

New Construction and Time of Sale (non-fuel switch only):

\[
\Delta \text{kWh} = [\text{Heating Savings}] + [\text{Cooling Savings}]
\]

\[
= [(\text{Elecheat} \times \text{Capacity}_{\text{heat}} \times \text{EFLH}_{\text{heat}} \times (1/\text{HSPF}_{\text{Base}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} \times \text{EFLH}_{\text{cool}} \times (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]
\]

New Construction and Time of Sale (fuel switch only):

- If measure is supported by gas utility only, \( \Delta \text{kWh} = 0 \)
- If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

\[
\Delta \text{kWh} = [\text{Heating Savings from base ASHP to DMSHP}] + [\text{Cooling Savings}]
\]

\[
= [(\text{Capacity}_{\text{heat}} \times \text{EFLH}_{\text{heat}} \times (1/\text{HSPF}_{\text{ASHP}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} \times \text{EFLH}_{\text{cool}} \times (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]
\]

Early replacement (non-fuel switch only):\(^{414}\)

**Early replacement (non-fuel switch only)**:

- If measure is supported by gas utility only, \( \Delta \text{kWh} = 0 \)
- If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

\[
\Delta \text{kWh} = [\text{Heating Savings from base ASHP to DMSHP}] + [\text{Cooling Savings}]
\]

\[
= [(\text{Capacity}_{\text{heat}} \times \text{EFLH}_{\text{heat}} \times (1/\text{HSPF}_{\text{ASHP}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} \times \text{EFLH}_{\text{cool}} \times (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]
\]

**Early replacement - fuel switch only**:

- If measure is supported by gas utility only, \( \Delta \text{kWh} = 0 \)
- If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

\[
\Delta \text{kWh} = [\text{Heating Savings from base ASHP to DMSHP}] + [\text{Cooling Savings}]
\]

\[
= [(\text{Capacity}_{\text{heat}} \times \text{EFLH}_{\text{heat}} \times (1/\text{HSPF}_{\text{ASHP}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} \times \text{EFLH}_{\text{cool}} \times (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]
\]

\[\text{414 The two equations are provided to show how savings are determined during the initial phase of the measure (existing to efficient) and the remaining phase (new baseline to efficient). In practice, the screening tools used may either require a First Year savings (using the first equation) and then a “number of years to adjustment” and “savings adjustment” input which would be the (new base to efficient savings)/(existing to efficient savings).}\]
= [(Capacity_{heat} \cdot \text{EFLH}_{heat} \cdot (1/\text{HSPF}_{ASHP} - 1/\text{HSPF}_{existing})) / 1000] + [(\text{Capacity}_{cool} \cdot \text{EFLH}_{cool} \cdot (1/\text{SEER}_{base} - 1/\text{SEER}_{existing})) / 1000]

Where:

- **ElecHeat** = 1 if existing building is electrically heated
  = 0 if existing building is not electrically heated
- **Capacity_{heat}** = Heating capacity of the ductless heat pump unit in Btu/hr
  = Actual
- **EFLH_{heat}** = Equivalent Full Load Hours for heating. Depends on location. See table below

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>EFLH_{heat}^{415}</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,520</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,421</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,347</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>977</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>994</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>1,406</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Existing Heating System</th>
<th>HSPF_{base}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.2</td>
</tr>
<tr>
<td>Electric Resistance</td>
<td>3.41^{416}</td>
</tr>
</tbody>
</table>

- **HSPF_{existing}** = HSPF rating of existing equipment (kbtu/kwh)
  = Use actual HSPF rating where it is possible to measure or reasonably estimate. If unknown assume default:

<table>
<thead>
<tr>
<th>Existing Equipment Type</th>
<th>HSPF_{existing}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric resistance heating</td>
<td>3.412^{417}</td>
</tr>
<tr>
<td>Air Source Heat Pump</td>
<td>5.44^{418}</td>
</tr>
</tbody>
</table>

- **HSPF_{ASHP}** = Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)
  = 8.2^{419}

---

^{415} All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015. FLH values are based on metering of multi-family units that were used as the primary heating source to the whole home, and in buildings that had received weatherization improvements. A DMSPHP installed in a single-family home may be used more sporadically, especially if the DMSPHP serves only a room, and buildings that have not been weatherized may require longer hours. Additional evaluation is recommended to refine the EFLH assumptions for the general population.

^{416} Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

^{417} Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

^{418} This is from the ASHP measure which estimated HSPF 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 average nameplate SEER rating of all Early Replacement qualifying equipment in Ameren PY3-PY4. This estimation methodology appears to provide a result within 10% of actual HSPF.

HSPF<sub>ee</sub> = HSPF rating of new equipment (kbtu/kwh)

= Actual installed

Capacity<sub>cool</sub> = the cooling capacity of the ductless heat pump unit in Btu/hr<sup>420</sup>.

= Actual installed

SEER<sub>base</sub> = SEER Efficiency of new replacement baseline unit

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>SEER&lt;sub&gt;base&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>14&lt;sup&gt;421&lt;/sup&gt;</td>
</tr>
<tr>
<td>Central AC</td>
<td>13&lt;sup&gt;422&lt;/sup&gt;</td>
</tr>
<tr>
<td>No central cooling</td>
<td>13&lt;sup&gt;423&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

SEER<sub>ee</sub> = SEER rating of new equipment (kbtu/kwh)

= Actual installed<sup>424</sup>

SEER<sub>exist</sub> = SEER rating of existing equipment (kbtu/kwh)

= Use actual value. If unknown, see table below

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>SEER&lt;sub&gt;exist&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>9.12</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.60</td>
</tr>
<tr>
<td>Room AC</td>
<td>8.0&lt;sup&gt;426&lt;/sup&gt;</td>
</tr>
<tr>
<td>No existing cooling&lt;sup&gt;427&lt;/sup&gt;</td>
<td>Make '1/SEER&lt;sub&gt;exist&lt;/sub&gt;' = 0</td>
</tr>
</tbody>
</table>

EFLH<sub>cool</sub> = Equivalent Full Load Hours for cooling. Depends on location. See table below<sup>428</sup>.

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>EFLH&lt;sub&gt;cool&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>323</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>308</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>468</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>629</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>549</td>
</tr>
</tbody>
</table>

<sup>420</sup> 1 Ton = 12 kbtu/hr


<sup>423</sup> Assumes that the decision to replace existing systems includes desire to add cooling.

<sup>424</sup> Note that if only an EER rating is available, use the following conversion equation; EER<sub>base</sub> = (-0.02 * SEER<sub>base</sub><sup>2</sup>) + (1.12 * SEER). From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder.

<sup>425</sup> Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.


<sup>427</sup> If there is no existing cooling in place but the incentive encourages installation of a new DMSHP with cooling, the added cooling load should be subtracted from any heating benefit.

<sup>428</sup> All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015. FLH values are based on metering of multi-family units, and in buildings that had received weatherization improvements. Additional evaluation is recommended to refine the EFLH assumptions for the general population.
Climate Zone (City based upon) | EFLH_{cool}
---|---
Weighted Average\(^{429}\) | 364

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>EFLH_{cool}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted Average(^{429})</td>
<td>364</td>
</tr>
</tbody>
</table>

For example, installing a 1.5-ton (heating and cooling capacity) ductless heat pump unit rated at 8 HSPF and 14 SEER in a single-family home in Chicago to displace electric baseboard heat and replace a window air conditioner of unknown efficiency, savings are:

\[
\Delta kW_{\text{Heat}} = \frac{(18000 \times 1421 \times (1/3.412 - 1/8))}{1000} = 4,299 \text{ kWh}
\]

\[
\Delta kW_{\text{Cool}} = \frac{(18000 \times 308 \times (1/8.0 - 1/14))}{1000} = 297 \text{ kWh}
\]

\[
\Delta kW = 4,299 + 297 = 4,596 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

New Construction and Time of Sale:

\[
\Delta kW = (\text{Capacity}_{\text{cool}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{exist}})) / 1000) \times \text{CF}
\]

Early replacement:

\[
\Delta kW \text{ for remaining life of existing unit (1st 6 years)}:\
\Delta kW = (\text{Capacity}_{\text{cool}} \times (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{exist}})) / 1000) \times \text{CF}
\]

\[
\Delta kW \text{ for remaining measure life (next 12 years)}:\
\Delta kW = (\text{Capacity}_{\text{cool}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{exist}})) / 1000) \times \text{CF}
\]

Where:

\[
\text{EER}_{\text{base}} = \text{EER Efficiency of new replacement unit}
\]

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>EER _base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>11.8(^{430})</td>
</tr>
<tr>
<td>Central AC</td>
<td>11 (^{431})</td>
</tr>
<tr>
<td>No central cooling</td>
<td>11 (^{432})</td>
</tr>
</tbody>
</table>

\[
\text{EER}_{\text{exist}} = \text{Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)}
\]

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

\[
\text{EER}_{\text{exist}} = (-0.02 \times \text{SEER}_{\text{exist}}^2) + (1.12 \times \text{SEER}_{\text{exist}}) \quad 433
\]

If SEER rating unavailable use:

---

\(^{429}\) Weighted based on number of residential occupied housing units in each zone.

\(^{430}\) The Federal Standard does not include an EER requirement, so it is approximated with the conversion formula from Wassmer, M. 2003 thesis referenced below.


\(^{432}\) Assumes that the decision to replace existing systems includes desire to add cooling.

### Existing Cooling System

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>EER_exist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.55</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.15</td>
</tr>
<tr>
<td>Room AC</td>
<td>7.7</td>
</tr>
<tr>
<td>No existing cooling</td>
<td>Make ‘1/EER_exist’ = 0</td>
</tr>
</tbody>
</table>

$EER_{ee}$ = Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)

$=$ Actual, If not provided convert SEER to EER using this formula: $438$

$=$ $(−0.02 \times SEER^2) + (1.12 \times SEER)$

**For supplemental or limited zonal cooling:**

$CF_{SSP}$ = Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)

$CF_{SSP} = 43.1\%$ $439$

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)

$CF_{PJM} = 28.0\%$ $440$

**For whole house cooling:**

$CF_{SSP}$ = Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)

$CF_{SSP} = 72\%$ $441$

$CF_{PJM}$ = PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)

$CF_{PJM} = 46.6\%$ $442$

### Natural Gas Savings

**New Construction and Time of Sale with baseline gas heat:**

If measure is supported by gas utility only, gas utility claim savings calculated below:

$Δ$Therms = $[\text{Heating Savings}]$

$= [\text{Replaced gas consumption} − \text{therm equivalent of DMSHP source kWh}]$

$= [(1 − \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbase}) − (\text{kWh}_\text{to}_\text{Therm} \times \text{Capacity}_\text{heat} \times \text{AFUEbase}))]$  

---

434 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

435 Ibid.


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


439 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

440 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

441 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.


442 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
EFLH_{heate} \cdot \frac{1}{HSPF_{ee}})]

If measure is supported by electric utility only, ΔTherms = 0
If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

\[ \Delta \text{Therms} = \text{[Heating Savings]} \]
\[ = \text{[Replaced gas consumption – therm equivalent of base ASHP source kWh]} \]
\[ = [(1 - \text{ElecHeat}) \cdot ((\text{Gas\_Heating\_Load}/\text{AFUEbase}) - (\text{kWhtoTherm} \cdot \text{Capacity}_{\text{heat}} \cdot \text{EFLH}_{\text{heate}} \cdot \frac{1}{HSPF_{\text{ee}}})/1000)] \]

Early replacement for homes with existing gas heat:

If measure is supported by gas utility only, gas utility claim savings calculated below:

\[ \Delta \text{Therms} \text{ for remaining life of existing unit (1st 6 years):} \]
\[ = \text{[Heating Savings]} \]
\[ = \text{[Replaced gas consumption – therm equivalent of DMSHP source kWh]} \]
\[ = [(1 - \text{ElecHeat}) \cdot ((\text{Gas\_Heating\_Load}/\text{AFUEexist}) - (\text{kWhtoTherm} \cdot \text{Capacity}_{\text{heat}} \cdot \text{EFLH}_{\text{heate}} \cdot \frac{1}{HSPF_{\text{ee}}})/1000)] \]

\[ \Delta \text{Therms} \text{ for remaining measure life (next 12 years):} \]
\[ = [(1 - \text{ElecHeat}) \cdot ((\text{Gas\_Heating\_Load}/\text{AFUEbaseER}) - (\text{kWhtoTherm} \cdot \text{Capacity}_{\text{heat}} \cdot \text{EFLH}_{\text{heate}} \cdot \frac{1}{HSPF_{\text{ee}}})/1000)] \]

If measure is supported by electric utility only, ΔTherms = 0
If measure is supported by gas and electric utility, gas utility claim savings calculated below:

\[ \Delta \text{Therms} \text{ for remaining life of existing unit (1st 6 years):} \]
\[ \Delta \text{Therms} = \text{[Heating Savings]} \]
\[ = \text{[Replaced gas consumption – therm equivalent of base ASHP source kWh]} \]
\[ = [(1 - \text{ElecHeat}) \cdot ((\text{Gas\_Heating\_Load}/\text{AFUEexist}) - (\text{kWhtoTherm} \cdot \text{Capacity}_{\text{heat}} \cdot \text{EFLH}_{\text{heate}} \cdot \frac{1}{HSPF_{\text{ee}}})/1000)] \]

\[ \Delta \text{Therms} \text{ for remaining measure life (next 12 years):} \]
\[ = [(1 - \text{ElecHeat}) \cdot ((\text{Gas\_Heating\_Load}/\text{AFUEbaseER}) - (\text{kWhtoTherm} \cdot \text{Capacity}_{\text{heat}} \cdot \text{EFLH}_{\text{heate}} \cdot \frac{1}{HSPF_{\text{ee}}})/1000)] \]

Where:

\text{ElecHeat} = 1 \text{ if existing building is electrically heated}
\text{ElecHeat} = 0 \text{ if existing building is not electrically heated}

\text{Gas\_Heating\_Load}

= \text{Estimate of annual household heating load}^{443} \text{ for gas furnace heated single-family homes. If location is unknown, assume the average below.}
\text{Gas\_Heating\_Load}

= \text{Actual if informed by site-specific load calculations, ACCA Manual J or equivalent}^{444}.

---

^{443} \text{Heating load is used to describe the household heating need, which is equal to (gas consumption} \times \text{AFUE)}

^{444} \text{The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing}
Climate Zone (City based upon) | Gas_Heating_Load if Furnace (therms) | Gas_Heating_Load if Boiler (therms)
---|---|---
1 (Rockford) | 873 | 1275
2 (Chicago) | 834 | 1218
3 (Springfield) | 714 | 1043
4 (Belleville) | 551 | 805
5 (Marion) | 561 | 819
Average | 793 | 1158

**AFUEbase**
- Baseline Annual Fuel Utilization Efficiency Rating
- 80% if furnace and 82% if boiler.

**AFUEexist**
- Existing Annual Fuel Utilization Efficiency Rating
- Use actual AFUE rating where it is possible to measure or reasonably estimate.
If unknown, assume 64.4% if furnace and 61.6% if boiler.

**AFUEbaseER**
- Baseline Annual Fuel Utilization Efficiency Rating for early replacement measure
- 90% if furnace and 82% if boiler.

**kWhtoTherm**
- Converts source kWh to Therms

\[
\text{kWh}_\text{grid} \times \frac{100000}{10^{6}}
\]
- Heat rate of the grid in btu/kWh based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

- Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory (including independent providers connected to RFC West), and SERC Midwest region for Ameren territory (including independent providers connected to SERC Midwest).

- Also include any line losses.

**loads** for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations are commonly completed by contractors during the selection process and may be readily available for program data purposes.

**444** Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, *Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study* (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

**446** Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, *Nicor R29 Res Rebate Evaluation Report 092611_REV_FINAL to Nicor* (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

**447** Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

**448** Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

**449** These values are subject to regular updates so should be reviewed regularly to ensure the current assumptions are correct.

Refer to the latest EPA eGRID data. Current values, based on eGrid 2014 are:

- Non-Baseload RFC West: 9,346 Btu/kWh * (1 + Line Losses)
- Non-Baseload SERC Midwest: 9,157 Btu/kWh * (1 + Line Losses)
- All Fossil Average RFC West: 9,931 Btu/kWh * (1 + Line Losses)
For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

All other variables provided above

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**COST EFFECTIVENESS SCREENING AND LOAD REDUCTION FORECASTING WHEN FUEL SWITCHING**

This measure can involve fuel switching from gas to electric.

For the purposes of forecasting load reductions due to fuel switch DMSHP projects per Section 16-111.5B, changes in site energy use at the customer’s meter (using ΔkWh algorithm below) adjusted for utility line losses (at-the-busbar savings), customer switching estimates, NTG, and any other adjustment factors deemed appropriate, should be used.

The inputs to cost effectiveness screening should reflect the actual impacts on the electric and fuel consumption at the customer meter and, for fuel switching measures, this will not match the output of the calculation/allocation methodology presented in the “Electric Energy Savings” and “Natural Gas Savings” sections above. Therefore in addition to the calculation of savings claimed, the following values should be used to assess the cost effectiveness of the measure.

\[
\Delta\text{Therms} = [\text{Heating Consumption Replaced}^{450}] \\
= [(1 – \text{ElecHeat}) \times \text{(Gas_Heating_Load/AFUEbase)}] \\
\Delta\text{kWh} = -[\text{DMSHP heating consumption}] + [\text{Cooling savings}^{451}] \\
= -[\text{Capacity}_\text{heat} \times \text{EFLH}_{\text{heat}} \times \frac{1}{\text{HSPFee}}] / 1000 + [(\text{Capacity}_\text{cool} \times \text{EFLH}_{\text{cool}} \times (\frac{1}{\text{SEER}_{\text{base}} – 1/\text{SEER}_{\text{e}}}) / 1000]
\]

**MEASURE CODE: RS-HVC-DHP-V05-180101**

**REVIEW DEADLINE: 1/1/2020**

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450 Note AFUEbase in the algorithm should be replaced with AFUExist for early replacement measures.

451 Note SEERbase in the algorithm should be replaced with SEERexist for early replacement measures.
5.3.13 Residential Furnace Tune-Up

**DESCRIPTION**

This measure is for a natural gas Residential furnace that provides space heating. The tune-up will improve furnace performance by inspecting, cleaning and adjusting the furnace and appurtenances for correct and efficient operation. Additional savings maybe realized through a complete system tune-up.

Two savings algorithms are provided for tune-up programs: through the HVAC SAVE program and for other tune-up programs, the difference being how relative efficiencies are measured.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure an approved technician must complete the tune-up requirements listed below:

- Measure combustion efficiency using an electronic flue gas analyzer
- Check and clean blower assembly and components per manufacturer’s recommendations
- Where applicable Lubricate motor and inspect and replace fan belt if required
- Inspect for gas leaks
- Clean burner per manufacturer’s recommendations and adjust as needed
- Check ignition system and safety systems and clean and adjust as needed
- Check and clean heat exchanger per manufacturer’s recommendations
- Inspect exhaust/flue for proper attachment and operation
- Inspect control box, wiring and controls for proper connections and performance
- Check air filter and clean or replace per manufacturer’s
- Check duct work connected to furnace for leaks or blockages
- Measure temperature rise and adjust flow as needed
- Check for correct line and load volts/amps
- Check thermostat operation is per manufacturer’s recommendations (if adjustments made, refer to ‘Residential Programmable Thermostat’ measure for savings estimate)
- Perform Carbon Monoxide test and adjust heating system until results are within standard industry acceptable limits

Verified Quality Maintenance:

This approach uses in-field measurement and interpretation of static pressures, identification and plotting of airflow, airflow measurement, temperature measurement and diagnostics, pressure measurements and duct design, and BTU measurement to ensure that existing equipment is operating according to manufacturers’ published potential performance. Installed equipment operating efficiency is largely dependent on the efficiency rating of the equipment, the skill of the installation contractor, the degree to which the equipment has aged or drifted from initial settings, and the system level constraints. When one or more of these key dependencies are operating sub-optimally, the overall efficiency of the equipment is degraded. A Verified Quality Maintenance identifies sub-optimal performance and prescribes a solution during furnace tune ups.

The HVAC SAVE program has its own certifications and requirements. In addition to the maintenance described above, the following are key activities that are provided through an HVAC SAVE Verified Quality Maintenance visit:

- Measure pressure drops at return, filter, coil and supply.
- Determine equipment air flow using OEM blower data or measuring.
- Measure temperature rise across heat exchanger.

---

452 American Standard Maintenance for Indoor Units: http://www.americanstandardair.com/owner-support/maintenance.html
453 As provided in ANSI approved ACCA 4 specification for Quality Maintenance
- Determine on-rate for a furnace by clocking the gas meter.
- Record outdoor temperature & elevation, and complete test-in.
- Clean evaporator coil to OEM pressure drop specification.
- Clean/replace/modify air filter to OEM pressure drop specification.
- Reset air flow based on up design parameter and updated pressure conditions.
- Adjust/modify gas pressure and venting to OEM specifications.
- Complete final test-out, compare before and after

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is furnace assumed not to have had a tune-up in the past 2 years.

HVAC SAVE tune-ups are a one-time measure and cannot be performed more than once on the same piece of equipment.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life for the tune up is 2 years.\(^{*}^{454}\)

An HVAC SAVE tune-up lasts the remaining life of the equipment because they come from adjustments to fans and ducts that remain effective through normal operation of the equipment. Assume 10 years.

**DEEMED MEASURE COST**

The incremental cost for this measure should be the actual cost of tune up.

**DEEMED O&M COST ADJUSTMENTS**

There are no expected O&M savings associated with this measure.

**LOADSHAPE**

Loadshape R09 - Residential Electric Space Heat

**COINCIDENCE FACTOR**

N/A

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**Algorithms**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = \Delta \text{Therms} \times F_e \times 29.3 \]

Where:

- \( \Delta \text{Therms} \) = as calculated below
- \( F_e \) = Furnace Fan energy consumption as a percentage of annual fuel consumption
  \[ = 3.14\% \] \(^{*}^{455}\)

---


\(^{*}^{455}\) \( F_e \) is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a
29.3 \( = \) kWh per therm

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

1. **Verified Quality Maintenance:**

\[
\Delta \text{Therms} = ( \text{Gas\_Furnace\_Heating\_Load} * \text{HF} * (1 / (\text{AFUE} * (1 - \text{Derating}_\text{pre})) - 1 / (\text{AFUE} * (1 - \text{Derating}_\text{post})))
\]

Where:

- \( \text{Gas\_Furnace\_Heating\_Load} \) = Estimate of annual household heating load\(^{456}\) for gas furnace heated single-family homes. If location is unknown, assume the average below\(^{457}\).
- \( \text{HF} \) = Actual if informed by site-specific load calculations, ACCA Manual J or equivalent\(^{458}\).
- \( \text{AFUE} \) = Furnace Annual Fuel Utilization Efficiency Rating

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas_Furnace_Heating_Load (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>873</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>834</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>714</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>551</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>561</td>
</tr>
<tr>
<td>Average</td>
<td>793</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Household Type</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>100%</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>65%(^{459})</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom(^{460})</td>
</tr>
</tbody>
</table>

**Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)**

**Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)**

\(^{456}\) Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE).

\(^{457}\) Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE).

\(^{458}\) Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city's HDD.


\(^{460}\) Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.
Derating\text{pre} = \text{Furnace AFUE Derating before HVAC SAVE tune-up} \\
= 6.4\%^{461} \\
Derating\text{post} = \text{Furnace AFUE Derating after HVAC SAVE tune-up} \\
= 0\%

2. Other Tune-Up Programs:

\[ \Delta\text{Therms} = (\text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \times \text{HF} \times (1/ \text{Effbefore} - 1/(\text{Effbefore} + \text{Ei}))) \]

Where:

\text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} = \text{Estimate of annual household heating load}^{462} \text{ for gas furnace heated single-family homes. If location is unknown, assume the average below}^{463}.

\text{HF} = \text{Household factor, to adjust heating consumption for non-single-family households.}

\begin{tabular}{|c|c|}
\hline
Climate Zone & Gas\_Furnace\_Heating\_Load \\
\text{(City based upon)} & \text{(therms)} \\
\hline
1 (Rockford) & 873 \\
2 (Chicago) & 834 \\
3 (Springfield) & 714 \\
4 (Belleville) & 551 \\
5 (Marion) & 561 \\
Average & 793 \\
\hline
\end{tabular}

\text{Effbefore} = \text{Efficiency of the furnace before the tune-up} \\
= \text{Actual}

\textit{Note: Contractors should select a mid-level firing rate that appropriately represents the average building operating condition over the course of the heating season and take readings at a consistent firing rate for pre and post tune-up.}

---


462 Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE).

463 Values are based on household heating consumption values and inferred average AFUE results from Table 2-1, Energy Efficiency / Demand Response Nicor Gas Plan Year 1 (6/1/2011-5/31/2012) Research Report: Furnace Metering Study (August 1, 2013) (prepared by Navigant Consulting, Inc.) and adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.


465 Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% factor is applied to MF homes, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes.

466 Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.
EI = Efficiency Improvement of the furnace tune-up measure
    = Actual

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HVC-FTUN-V03-180101**

**REVIEW DEADLINE: 1/1/2021**
5.3.14 Boiler Reset Controls

**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.\(^{467}\)

This measure was developed to be applicable to the following program types: RF.

**DEFINITION OF EFFICIENT EQUIPMENT**

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.

**DEFINITION OF BASELINE EQUIPMENT**

Existing condensing boiler in a single family residential setting without boiler reset controls.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The life of this measure is 20 years\(^ {468}\).

**DEEMED MEASURE COST**

The cost of this measure is $612\(^ {469}\).

**LOADSHAPE**

NA

**COINCIDENCE FACTOR**

N/A

---

\(^{467}\)Energy Solutions Center, a consortium of natural gas utilities, equipment manufacturers and vendors. Boiler Reset Control, accessed at http://naturalgasefficiency.org/residential/Boiler_Reset_Control.htm

\(^{468}\)CLEA Result references the Brooklyn Union Gas Company, High Efficiency Heating and Water and Controls, Gas Energy Efficiency Program Implementation Plan.

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS
N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS
NA

NATURAL GAS SAVINGS

\[ \Delta \text{Therms} = \text{Gas}_\text{Boiler}_\text{Load} \times \left(\frac{1}{\text{AFUE}}\right) \times \text{Savings\ Factor} \]

Where:

\[ \text{Gas}_\text{Boiler}_\text{Load} \]

= Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below.

= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent.

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas Boiler Load (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1275</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1218</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1043</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>805</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>819</td>
</tr>
<tr>
<td>Average</td>
<td>1158</td>
</tr>
</tbody>
</table>

AFUE

= Existing Condensing Boiler Annual Fuel Utilization Efficiency Rating

= Actual.

SF

= Savings Factor, 5%  

---

470 Boiler consumption values are informed by an evaluation which did not identify any fraction of heating load due to domestic hot water (DHW) provided by the boiler. Thus these values are an average of both homes with boilers only providing heat, and homes with boilers that also provide DHW. Heating load is used to describe the household heating need, which is equal to (gas heating consumption * AFUE).

471 Values are based on household heating consumption values and inferred average AFUE results from Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor. Adjusting to a statewide average using relative HDD values to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

472 The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8th Edition produces equipment sizing loads for Single Family, Multi-single, and Condominiums using input characteristics of the home. A best practice for equipment selection and installation of Heating and Air Conditioning, load calculations should be completed by contractors during the selection process and may be readily available for program data purposes.

EXAMPLE
For example, boiler reset controls on a 92.5 AFUE boiler at a household in Rockford, IL

\[ \Delta \text{Therms} = 1275 \times (1/0.925) \times 0.05 \]
\[ = 69 \text{ Therms} \]

WATER IMPACT DESCRIPTIONS AND CALCULATION
N/A

DEEMED O&M COST ADJUSTMENT CALCULATION
N/A

MEASURE CODE: RS-HVC-BREC-V01-150601

REVIEW DEADLINE: 1/1/2021
5.3.15 ENERGY STAR Ceiling Fan

DESCRIPTION
A ceiling fan/light unit meeting the efficiency specifications of ENERGY STAR 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\(^{474}\).

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 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
The efficient equipment is defined as an ENERGY STAR certified ceiling fan with integral CFL bulbs.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is assumed to be a standard fan with efficient incandescent or halogen light bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012 followed by restrictions on 75W in 2013 and 60W and 40W in 2014, due to the Energy Independence and Security Act of 2007 (EISA). Finally, a provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) for the lighting portion of the savings should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The fan savings measure life is assumed to be 10 years.\(^2\)

The lighting savings measure life is assumed to be 3 years for lighting savings for units installed in 2018, and then for every subsequent year should be reduced by one year\(^{475}\) (see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure).

DEEMED MEASURE COST
Incremental cost of unit is $46.\(^{476}\)

LOADSHAPE
R06 - Residential Indoor Lighting
R11 - Residential Ventilation

\(^{474}\) http://www.energystar.gov/products/certified-products/detail/ceiling-fans

\(^{475}\) Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

\(^{476}\) ENERGY STAR Ceiling Fan Savings Calculator
COINCIDENCE FACTOR

The summer peak coincidence factor for the ventilation savings is assumed to be 30%.\(^{477}\)

For lighting savings, see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta k\text{Wh} = \Delta k\text{Wh}_{\text{fan}} + \Delta k\text{Wh}_{\text{light}} \]

\[ \Delta k\text{Wh}_{\text{fan}} = \left[ \text{Days} \ast \text{FanHours} \ast \left( \%\text{Low}_{\text{base}} \ast \text{WattsLow}_{\text{base}} \right) + \left( \%\text{Med}_{\text{base}} \ast \text{WattsMed}_{\text{base}} \right) + \left( \%\text{High}_{\text{base}} \ast \text{WattsHigh}_{\text{base}} \right) \right] / 1000 \] \[ - \left[ \text{Days} \ast \text{FanHours} \ast \left( \%\text{Low}_{\text{ES}} \ast \text{WattsLow}_{\text{ES}} \right) + \left( \%\text{Med}_{\text{ES}} \ast \text{WattsMed}_{\text{ES}} \right) + \left( \%\text{High}_{\text{ES}} \ast \text{WattsHigh}_{\text{ES}} \right) \right] / 1000 \]

\[ \Delta k\text{Wh}_{\text{light}} = \text{see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.} \]

Where:\(^{478}\):

- Days = Days used per year
  - Actual. If unknown use 365.25 days/year
- FanHours = Daily Fan “On Hours”
  - Actual. If unknown use 3 hours
- \%Low\text{base} = Percent of time spent at Low speed of baseline
  - 40%
- WattsLow\text{base} = Fan wattage at Low speed of baseline
  - Actual. If unknown use 15 watts
- \%Med\text{base} = Percent of time spent at Medium speed of baseline
  - 40%
- WattsMed\text{base} = Fan wattage at Medium speed of baseline
  - Actual. If unknown use 34 watts
- \%High\text{base} = Percent of time spent at High speed of baseline
  - 20%
- WattsHigh\text{base} = Fan wattage at High speed of baseline
  - Actual. If unknown use 67 watts
- \%Low\text{ES} = Percent of time spent at Low speed of ENERGY STAR

\(^{477}\) Assuming that the CF same as a 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)

\(^{478}\) 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
\[ \text{WattsLow}_{\text{ES}} = \text{Fan wattage at Low speed of ENERGY STAR} \]
= Actual. If unknown use 6 watts

\[ \%\text{Med}_{\text{ES}} = \text{Percent of time spent at Medium speed of ENERGY STAR} \]
= 40%

\[ \text{WattsMed}_{\text{ES}} = \text{Fan wattage at Medium speed of ENERGY STAR} \]
= Actual. If unknown use 23 watts

\[ \%\text{High}_{\text{ES}} = \text{Percent of time spent at High speed of ENERGY STAR} \]
= 20%

\[ \text{WattsHigh}_{\text{ES}} = \text{Fan wattage at High speed of ENERGY STAR} \]
= Actual. If unknown use 56 watts

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

<table>
<thead>
<tr>
<th>Percent of Time at Given Speed</th>
<th>Low Speed</th>
<th>Medium Speed</th>
<th>High Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Unit Wattage</td>
<td>15</td>
<td>34</td>
<td>67</td>
</tr>
<tr>
<td>ENERGY STAR Unit Wattage</td>
<td>6</td>
<td>23</td>
<td>56</td>
</tr>
<tr>
<td>( \Delta W )</td>
<td>9</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

If the lighting WattsBase and WattsEE is unknown, assume the following:

\[ \text{WattsBase} = 3 \times 43 = 129 \text{ W} \]
\[ \text{WattsEE} = 1 \times 42 = 42 \text{ W} \]

**EXAMPLE**

For example, a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

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

\[ \Delta \text{kWh}_{\text{light}} = \left(129 - 42\right) / 1000 \times 759 \times 1.06 \]
\[ = 70.0 \text{ kWh} \]

\[ \Delta \text{kWh} = 11.2 + 70 \]
\[ = 81.2 \text{ kWh} \]

Using the default assumptions provided above, the deemed savings is 81.2 kWh.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kW_{\text{fan}} + \Delta kW_{\text{light}} \]
\[ \Delta kW_{\text{fan}} = \left(\text{WattsHigh}_{\text{base}} - \text{WattsHigh}_{\text{ES}}\right) / 1000 \times CF_{\text{fan}} \]
\[ \Delta kW_{\text{light}} = \text{see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.} \]

Where:

\[ CF_{\text{fan}} = \text{Summer Peak coincidence factor for ventilation savings} \]
\[ = 30\% \]  
\[ CF_{\text{light}} = \text{Summer Peak coincidence factor for lighting savings} \]
\[ = 7.1\% \]

**EXAMPLE**

For example a ceiling fan with three 43W bulb light fixtures, replaced with an ES ceiling fan with one 42W bulb light fixture, the savings are:

\[ \Delta kW_{\text{fan}} = ((67-56)/1000) \times 0.3 \]
\[ = 0.0033 \text{ kW} \]

\[ \Delta kW_{\text{light}} = ((129 - 42)/1000) \times 1.11 \times 0.071 \]
\[ = 0.0068 \text{ kW} \]

\[ \Delta kW = 0.0033 + 0.0068 \]
\[ = 0.010 \text{ kW} \]

Using the default assumptions provided above, the deemed savings is 0.010kW.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

See 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure for bulb replacement costs.

**MEASURE CODE: RS-HVC-CFAN-V02-180101**

**REVIEW DEADLINE: 1/1/2022**

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\[479\] Assuming that the CF same as a Room AC. Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008


\[480\] Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
5.3.16 Advanced Thermostats

DESCRIPTION

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature setpoints (like a programmable thermostat) and automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts. This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren’t yet established at the level of individual features, but rather at the system level and how it performs overall. Like programmable thermostats, it is not suitable to assume that heating and cooling savings follow a similar pattern of usage and savings opportunity, and so here too this measure treats these savings independently. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations. Energy savings are applicable at the household level; all thermostats controlling household heat should be programmable and installation of multiple advanced thermostats per home does not accrue additional savings. Note that though these devices and service could potentially be used as part of a demand response program, the costs, delivery, impacts, and other aspects of DR-specific program delivery are not included in this characterization at this time, though they could be added in the future.

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

DEFINITION OF EFFICIENT EQUIPMENT

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

DEFINITION OF BASELINE EQUIPMENT

The baseline is either the actual type (manual or programmable) if it is known, or an assumed mix of these two

481 For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home’s thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.
482 The ENERGY STAR program discontinued its support for basic programmable thermostats effective 12/31/09, and is presently developing a new specification for ‘Residential Climate Controls’.
483 This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. It is recommended that program implementations incorporate this data into their planning and operation activities to improve understanding of the measure to manage risks and enhance savings results.
484 If the actual thermostat is programmable and it is found to be used in override mode or otherwise effectively being operated like a manual thermostat, then the baseline may be considered to be a manual thermostat.
types based upon information available from evaluations or surveys that represent the population of program participants. This mix may vary by program, but as a default, 44% programmable and 56% manual thermostats may be assumed.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years based upon equipment life only.

**DEEMED MEASURE COST**

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used. For retail, Bring Your Own Thermostat (BYOT) programs, or other program types actual costs are still preferable but if unknown then the average incremental cost for the new installation measure is assumed to be $175.

**LOADSHAPE**

\[\Delta kWh \rightarrow \text{Loadshape R10 - Residential Electric Heating and Cooling} \]
\[\Delta kWh_{\text{heating}} \rightarrow \text{Loadshape R09 - Residential Electric Space Heat} \]
\[\Delta kWh_{\text{cooling}} \rightarrow \text{Loadshape R08 - Residential Cooling} \]

**COINCIDENCE FACTOR**

In the absence of conclusive results from empirical studies on peak savings, the TAC agreed to a temporary assumption of 50% of the cooling coincidence factor, acknowledging that while the savings from the advanced Thermostat will track with the cooling load, the impact during peak periods may be lower. This is an assumption that could use future evaluation to improve these estimates.

\[CF_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)} \]
\[CF_{\text{SSP}} = 34\% \]
\[CF_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[CF_{\text{PJM}} = 23.3\% \]

---


486 Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

487 Future evaluation is strongly encouraged to inform the persistence of savings to further refine measure life assumption. As this characterization depends heavily upon a number of savings studies that only lasted a single year or less, the longer term impacts should be assessed.

488 In contrast to program designs that utilize program affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation and other services, BYOT programs enroll customers after the time of purchase through online rebate and program integration sign-ups.

489 Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.

490 Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure’s eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

491 Assumes 50% of the cooling coincidence factor (based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory).

492 Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)
Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta kWh = \Delta kWh_{\text{heating}} + \Delta kWh_{\text{cooling}} \]

\[ \Delta kWh_{\text{heating}} = \% \text{ElectricHeat} \times \text{Elec\_Heating\_Consumption} \times \text{Heating\_Reduction} \times \text{HF} \times \text{Eff\_ISR} + (\Delta \text{Therms} \times F_e \times 29.3) \]

\[ \Delta kWh_{\text{cool}} = \% \text{AC} \times ((\text{FLH} \times \text{Btu/hr} \div 1/\text{SEER})/1000) \times \text{Cooling\_Reduction} \times \text{Eff\_ISR} \]

Where:

\%ElectricHeat = Percentage of heating savings assumed to be electric

<table>
<thead>
<tr>
<th>Heating fuel</th>
<th>%ElectricHeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>6.5%</td>
</tr>
</tbody>
</table>

Elec\_Heating\_Consumption

= Estimate of annual household heating consumption for electrically heated single-family homes. If location and heating type is unknown, assume 15,678 kWh.

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Electric Resistance Elec_Heating_Consumption (kWh)</th>
<th>Electric Heat Pump Elec_Heating_Consumption (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>21,741</td>
<td>12,789</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>20,771</td>
<td>12,218</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>17,789</td>
<td>10,464</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>13,722</td>
<td>8,072</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>13,966</td>
<td>8,215</td>
</tr>
<tr>
<td>Average</td>
<td>19,743</td>
<td>11,613</td>
</tr>
</tbody>
</table>

Heating\_Reduction = Assumed percentage reduction in total household heating energy

493 Electrical savings are a function of both heating and cooling energy usage reductions. For heating this is a function of the percent of electric heat (heat pumps) and fan savings in the case of a natural gas furnace.

494 Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat (consistent with Potential Study results from the state). Average value of 13% electric space heating from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

495 Values in table are based on converting an average household heating load (834 therms) for Chicago based on ‘Table E-1, Energy Efficiency/Demand Response Nicor Gas Plan Year 1: Research Report: Furnace Metering Study, Draft, Navigant, August 1 2013 to an electric heat load (divide by 0.03413) to electric resistance and ASHP heat load (resistance load reduced by 15% to account for distribution losses that occur in furnace heating but not in electric resistance while ASHP heat is assumed to suffer from similar distribution losses) and then to electric consumption assuming efficiencies of 100% for resistance and 200% for HP (see ‘Household Heating Load Summary Calculations_11062013.xls’). Finally these values were adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.

496 Assumption that 1/2 of electrically heated homes have electric resistance and 1/2 have Heat Pump, based on 2010 Residential Energy Consumption Survey for Illinois.
consumption due to advanced thermostat

<table>
<thead>
<tr>
<th>Existing Thermostat Type</th>
<th>Heating Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual</td>
<td>8.8%</td>
</tr>
<tr>
<td>Programmable</td>
<td>5.6%</td>
</tr>
<tr>
<td>Unknown (Blended)</td>
<td>7.4%</td>
</tr>
</tbody>
</table>

**HF** = Household factor, to adjust heating consumption for non-single-family households.

<table>
<thead>
<tr>
<th>Household Type</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>100%</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>65%</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom</td>
</tr>
</tbody>
</table>

**Eff_ISR** = Effective In-Service Rate, the percentage of thermostats installed and configured effectively for 2-way communication. Note that retrospective adjustments should be made during evaluation verification activities through the use of a realization rate if the program design does not ensure that each advanced thermostat is actually installed and/or if the evaluation determines that the advanced thermostat is not actually installed in the Program Administrator’s service territory.

<table>
<thead>
<tr>
<th>Program Delivery</th>
<th>Eff_ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install</td>
<td>100%</td>
</tr>
<tr>
<td>Other</td>
<td>100%</td>
</tr>
</tbody>
</table>

**ΔTherm** = Therm savings if Natural Gas heating system

- See calculation in Natural Gas section below

**F_e** = Furnace Fan energy consumption as a percentage of annual fuel consumption

- 3.14%\(^{501}\)

29.3 = kWh per therm

**%AC** = Fraction of customers with thermostat-controlled air-conditioning

\(^{497}\) These values represent adjusted baseline savings values (8.8% for manual, and 5.6% for programmable thermostats) as presented in Navigant’s PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of ’IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt’). These values are used as the basis for the weighted average savings value when the type of existing thermostat is not known. Using the default assumption of 56% manual and 44% programmable as described in the baseline definition section above the 7.4% savings value is equal to the sum of proportional savings for manual and programmable thermostats:  8.8% * 0.56 + 5.6% * 0.44. Further evaluation and regular review of this key assumption is encouraged.

\(^{498}\) Multifamily household heating consumption relative to single-family households is affected by overall household square footage and exposure to the exterior. This 65% reduction factor is applied to MF homes, based on professional judgment that average household size, and heat loads of MF households are smaller than single-family homes.

\(^{499}\) Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

\(^{500}\) As a function of the method for determining savings impact of these devices, in-service rate effects are already incorporated into the savings value for heating_reduction above.

\(^{501}\) F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, “~50% greater than the Energy Star version 3 criteria for 2% F_e”. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.
Thermostat control of air conditioning? & %AC
--- & ---
Yes & 100%
No & 0%
Unknown & 66%502
Unknown Multi-Family & 46%503
Unknown Single Family & 87%504

FLH = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type. If location and cooling type are unknown, assume the weighted average.

<table>
<thead>
<tr>
<th>Climate zone (city based upon)</th>
<th>FLH (single family)</th>
<th>FLH (general multifamily)</th>
<th>FLH_cooling (weatherized multi family)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
<td>243</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
<td>263</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
<td>345</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1035</td>
<td>940</td>
<td>489</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
<td>426</td>
</tr>
<tr>
<td>Weighted average508</td>
<td>629</td>
<td>564</td>
<td>293</td>
</tr>
</tbody>
</table>

Btu/hr = Size of AC unit509. (Note: One refrigeration ton is equal to 12,000 Btu/hr.)

<table>
<thead>
<tr>
<th>Program Delivery</th>
<th>Btu/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install (Single Family known, or MF)</td>
<td>Actual</td>
</tr>
<tr>
<td>Unknown (Single family home only)</td>
<td>33,600</td>
</tr>
</tbody>
</table>

SEER = the cooling equipment’s Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

= Use actual SEER rating where it is possible to measure or reasonably estimate.

<table>
<thead>
<tr>
<th>Cooling System</th>
<th>SEER510</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>9.12</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.60</td>
</tr>
</tbody>
</table>

1/1000 = kBtu per Btu

---

502 66% of homes in Illinois having central cooling ("Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey;


504 Ibid.

505 Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

506 Ibid.

507 All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015

508 Weighted based on number of residential occupied housing units in each zone.

509 Actual unit size required for multi-family building, no size assumption provided because the unit size and resulting savings can vary greatly depending on the number of units.

510 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
Cooling Reduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat:\[ 511 \]

For example, an advanced thermostat replacing a programmable thermostat directly installed in an electric heat pump heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

\[
\Delta kWH = \Delta kWH_{heating} + \Delta kWH_{cooling} \\
= 1 * 10,464 * 5.6% * 100% + (0 * 0.0314 * 29.3) + 100% * \left(\frac{(730 * 33,600 * (1/9.12))/1000}{8% * 100}\right) \\
= 586 kWh + 215 kWh \\
= 801 kWh
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \%AC * (\text{Cooling Reduction} * \text{Btu/hr} * (1/EER))/1000 * \text{EFF_ISR} * \text{CF}
\]

Where:

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

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

\[
EER = (-0.02 * \text{SEER}^2) + (1.12 \times \text{SEER}) \]

If SEER or EER rating unavailable use:

<table>
<thead>
<tr>
<th>Cooling System</th>
<th>EER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.55</td>
</tr>
<tr>
<td>Central AC</td>
<td>8.15</td>
</tr>
</tbody>
</table>

CFSSP = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 34%\[ 515 \]

CFPJM = PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)

---

511 The Technical Advisory Committee is currently collaborating on a plan for an upcoming evaluation that will relate to the exact population this measure represents, and results of that evaluation will be used to update this assumption when it is finalized.

512 This assumption is based upon the review of many evaluations from other regions in the US (see Navigant workpaper “Illinois Statewide TRM Workpaper_RES_Smart Thermostats_2015 11 02.docx” and VEIC summary “Studies informing the Illinois TRM Savings Characterization for Advanced Thermostats.docx”). These sources, are from different regions, products, and program delivery designs, but collectively form a sound basis, and directional guidance for the existence and magnitude of cooling savings. Because cooling savings are more volatile than those for heating due to variables in control behaviors, population, and product factors, conservatism is warranted and 8% was considered a conservative estimate based upon the array of results from these studies available at the time this value was developed. Further evaluation and regular review of this key assumption is encouraged.


514 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

515 Assumes 50% of the cooling coincidence factor (based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.)
\[
\text{\%FossilHeat} = 23.3\%^{516}
\]

Other variables as provided above

For example, an advanced thermostat replacing a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

\[
\Delta kW_{SSP} = 100\% \times 8\% \times 33,600 \times (1/8.15)/1000 \times 100\% \times 34\%
\]
\[
= 0.11 \text{ kW}
\]

\[
\Delta kW_{PJM} = 100\% \times 8\% \times 33,600 \times (1/8.15)/1000 \times 100\% \times 23.3\%
\]
\[
= 0.077 \text{ kW}
\]

**Natural Gas Energy Savings**

\[
\Delta \text{Therms} = \%\text{FossilHeat} \times \text{Gas}_\text{Heating}_\text{Consumption} \times \text{Heating}_\text{Reduction} \times \text{HF} \times \text{Eff}_\text{ISR}
\]

Where:

\[
\%\text{FossilHeat} = \text{Percentage of heating savings assumed to be Natural Gas}
\]

<table>
<thead>
<tr>
<th>Heating fuel</th>
<th>%FossilHeat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>93.5%^{517}</td>
</tr>
</tbody>
</table>

\[
\text{Gas}_\text{Heating}_\text{Consumption} = \text{Estimate of annual household heating consumption for gas heated single-family homes.}
\]

If location is unknown, assume the average below^{518}.

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas_Heating_Consumption (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>1,052</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>1,005</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>861</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>664</td>
</tr>
</tbody>
</table>

^{516} Assumes 50% of the cooling coincidence factor (based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.)

^{517} Assumes that half of the electric heat in the state is a heat pump able to be controlled by an advanced thermostat. Data from 2010 Residential Energy Consumption Survey for Illinois. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

^{518} Values are based on adjusting the average household heating consumption (849 therms) for Chicago based on ‘Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611_REV FINAL to Nicor’, calculating inferred heating load by dividing by average efficiency of new in program units in the study (94.4%) and then applying standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24*0.92) + (0.76*0.8) = 0.83). This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD.
<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Gas_Heating_Consumption (therms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (Marion)</td>
<td>676</td>
</tr>
<tr>
<td>Average</td>
<td>955</td>
</tr>
</tbody>
</table>

Other variables as provided above

For example, an advanced thermostat replacing a programmable thermostat directly-installed in a gas heated single-family home in Chicago:

\[
\Delta \text{Therms} = 1.0 \times 1005 \times 5.6\% \times 100\% \times 100\%
\]

\[
= 56.28 \text{ therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-HVC-ADTH-V02-180101

**REVIEW DEADLINE:** 1/1/2019
5.4 Hot Water End Use

5.4.1 Domestic Hot Water Pipe Insulation

**DESCRIPTION**

This measure describes adding insulation to un-insulated domestic hot water pipes. The measure assumes the pipe wrap is installed to the first length of both the hot and cold pipe up to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses. Default savings are provided per 3ft length and are appropriate up to 6ft of the hot water pipe and 3ft of the cold.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The efficient case is installing pipe wrap insulation to a length of hot water pipe.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is an un-insulated hot water pipe.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 15 years.\(^{519}\)

**DEEMED MEASURE COST**

The measure cost including material and installation is assumed to be $3 per linear foot.\(^{520}\)

**LOADSHAPE**

Loadshape C53 - Flat

**COINCIDENCE FACTOR**

This measure assumes a flat loadshape since savings relate to reducing standby losses and as such the coincidence factor is 1.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For electric DHW systems:

\[
\Delta \text{kWh} = \frac{(1/R_{\text{exist}} - 1/R_{\text{new}}) \times (L \times C) \times \Delta T \times 8,766}{\eta_{\text{DHW}} / 3413}
\]

Where:


\(^{520}\) Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
Rexist = Pipe heat loss coefficient of uninsulated pipe (existing) [(hr-°F-ft)/Btu]
= 1.0

Rnew = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]
= Actual (1.0 + R value of insulation)

L = Length of pipe from water heating source covered by pipe wrap (ft)
= Actual

C = Circumference of pipe (ft) (Diameter (in) * π/12)
= Actual (0.5" pipe = 0.131ft, 0.75" pipe = 0.196ft)

ΔT = Average temperature difference between supplied water and outside air temperature (°F)
= 60°F

8,766 = Hours per year

ηDHW = Recovery efficiency of electric hot water heater
= 0.98

3412 = Conversion from Btu to kWh

For example, insulating 5 feet of 0.75" pipe with R-5 wrap:

$$\Delta k\text{Wh} = \frac{((1/R\text{exist} - 1/R\text{new}) \times (L \times C) \times ΔT \times 8,766)}{η\text{DHW} / 3412}$$
$$= \frac{((1/1 - 1/(1+5)) \times (5 \times 0.196) \times 60 \times 8766)}{0.98 / 3412}$$
$$= 128 \text{ kWh}$$

If inputs above are not available the following default per 3ft R-5 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.

$$\Delta k\text{Wh} = \frac{((1/R\text{exist} - 1/R\text{new}) \times (L \times C) \times ΔT \times 8,766)}{η\text{DHW} / 3412}$$
$$= \frac{((1/1 - 1/(1+5)) \times (3 \times 0.196) \times 60 \times 8766)}{0.98 / 3412}$$
$$= 77.1 \text{ kWh per 3ft length}$$

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$ΔkW = Δk\text{Wh} / 8766$$

Where:

ΔkWh = kWh savings from pipe wrap installation

8766 = Number of hours in a year (since savings are assumed to be constant over year).

---


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

523 Electric water heaters have recovery efficiency of 98%: [http://www.ahridirectory.org/ahridirectory/pages/home.aspx](http://www.ahridirectory.org/ahridirectory/pages/home.aspx)
For example, insulating 5 feet of 0.75” pipe with R-5 wrap:
\[
\Delta kW = \frac{128}{8766} = 0.015 kW
\]

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6 ft length on the hot pipe and 3 ft on the cold pipe.
\[
\Delta kW = \frac{77.1}{8766} = 0.0088 kW
\]

**NATURAL GAS SAVINGS**

For Natural Gas DHW systems:
\[
\Delta \text{Therm} = \left(\frac{1}{R_{\text{exist}}} - \frac{1}{R_{\text{new}}}\right) \times (L \times C) \times \Delta T \times 8766 \div \eta \text{DHW} \div 100,000
\]

Where:
\[
\eta \text{DHW} = \text{Recovery efficiency of gas hot water heater}
\]
\[
= 0.78 \text{ 524}
\]

Other variables as defined above

For example, insulating 5 feet of 0.75” pipe with R-5 wrap:
\[
\Delta \text{Therm} = \left(\frac{1}{1-1/(1+5)}\right) \times (5 \times 0.196) \times 60 \times 8766 \div 0.78 \div 100,000
\]
\[
= 5.51 \text{ therms}
\]

If inputs above are not available the following default per 3ft R-4 length can be used for up to 6ft length on the hot pipe and 3ft on the cold pipe.
\[
\Delta \text{Therm} = \left(\frac{1}{R_{\text{exist}} - 1/R_{\text{new}}}\right) \times (L \times C) \times \Delta T \times 8766 \div \eta \text{DHW} \div 100,000
\]
\[
= \left(\frac{1}{1-1/(1+5)}\right) \times (3 \times 0.196) \times 60 \times 8766 \div 0.78 \div 100,000
\]
\[
= 3.30 \text{ therms per 3ft length}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-PINS-V02-150601**

**REVIEW DEADLINE: 1/1/2019**

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524 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 78%
5.4.2 Gas Water Heater

DESCRIPTION

This measure characterizes:

a) Time of sale or new construction:
   The purchase and installation of a new efficient gas-fired water heater, in place of a Federal Standard unit in a residential setting. Savings are provided for power-vented, condensing storage, and whole-house tankless units meeting specific EF criteria.

b) Early replacement:
   The early removal of an existing functioning natural gas water heater from service, prior to its natural end of life, and replacement with a new high efficiency unit. Savings are calculated between existing unit and efficient unit consumption during the remaining life of the existing unit, and between new baseline unit and efficient unit consumption for the remainder of the measure life.

This measure was developed to be applicable to the following program types: TOS, NC, EREP.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the efficient equipment must be a water heater rated with the following minimum efficiency ratings:

<table>
<thead>
<tr>
<th>Water Heater Type</th>
<th>Minimum Energy Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage</td>
<td>0.67</td>
</tr>
<tr>
<td>Condensing gas storage</td>
<td>0.80</td>
</tr>
<tr>
<td>Tankless whole-house unit</td>
<td>0.82</td>
</tr>
</tbody>
</table>

DEFINITION OF BASELINE EQUIPMENT

Time of Sale or New Construction: The baseline condition is assumed to be a standard gas storage water heater of the same capacity as the efficient unit, rated at the federal minimum. For 20 to 55 gallon tanks the Federal Standard is calculated as 0.675 – (0.0015 * storage size in gallons) and for tanks 55 - 100 gallon 0.8012 – (0.00078 * storage size in gallons).525 For a 40-gallon storage water heater this would be 0.615 EF.

Early replacement: The baseline for this measure is the efficiency of the existing equipment for the assumed remaining useful life of the unit and a new baseline unit for the remainder of the measure life.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.526

For early replacement: Remaining life of existing equipment is assumed to be 4 years.527

525 Minimum Federal Standard as of 4/1/2015;
526 DOE, 2010 Residential Heating Products Final Rule Technical Support Document, Table 8.2.14
http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch8.pdf Note: This source is used to support this category in aggregate. For all water heaters, life expectancy will depend on local variables such as water chemistry and homeowner maintenance. Some categories, including condensing storage and tankless water heaters do not yet have sufficient field data to support separate values. Preliminary data show lifetimes may exceed 20 years, though this has yet to be sufficiently demonstrated.
527 Assumed to be one third of effective useful life
DEEMED MEASURE COST

Time of Sale or New Construction:

The incremental capital cost for this measure is dependent on the type of water heater as listed below.\textsuperscript{528}

Early Replacement: The full installed cost is provided in the table below. The assumed deferred cost (after 4 years) of replacing existing equipment with a new baseline unit is assumed to be $650\textsuperscript{529}. This cost should be discounted to present value using the nominal discount rate.

<table>
<thead>
<tr>
<th>Water heater Type</th>
<th>Incremental Cost</th>
<th>Full Install Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Storage</td>
<td>$400</td>
<td>$1014</td>
</tr>
<tr>
<td>Condensing gas storage</td>
<td>$685</td>
<td>$1299</td>
</tr>
<tr>
<td>Tankless whole-house unit</td>
<td>$605</td>
<td>$1219</td>
</tr>
</tbody>
</table>

LOADSHAPE

N/A

COINCIDENCE FACTOR

N/A

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

N/A

SUMMER COINCIDENT PEAK DEMAND SAVINGS

N/A

NATURAL GAS ENERGY SAVINGS

Time of Sale or New Construction:

\[ \Delta \text{Therms} = \frac{(1/ \text{EF}_{\text{BASE}} - 1/ \text{EF}_{\text{EFFICIENT}}) \times (\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)}{100,000} \]

Early replacement\textsuperscript{530}:

\[ \Delta \text{Therms} \text{ for remaining life of existing unit (1st 4 years):} \]

\[ = \left(\frac{1}{\text{EF}_{\text{EXISTING}} - 1/ \text{EF}_{\text{EFFICIENT}}}\right) \times (\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) /100,000 \]

\[ \Delta \text{Therms} \text{ for remaining measure life (next 9 years):} \]

\[ = \frac{(1/ \text{EF}_{\text{EXISTING}} - 1/ \text{EF}_{\text{EFFICIENT}}) \times (\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)}{100,000} \]


\textsuperscript{529} The deemed install cost of a Gas Storage heater is based upon DCEO Efficient Living Program Data for a sample size of 157 gas water heaters, and applying inflation rate of 1.91%.

\textsuperscript{530} 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).
\[
= \frac{(1/ \text{EF}_{\text{BASE}} - 1/\text{EF}_{\text{EFFICIENT}}) \cdot (\text{GPD} \cdot \text{Household} \cdot 365.25 \cdot \gamma_{\text{Water}} \cdot (T_{\text{OUT}} - T_{\text{IN}}) \cdot 1.0)}{100,000}
\]

Where:

- \text{EF}_{\text{Baseline}} = \text{Energy Factor rating for baseline equipment}
  - For \leq 55 \text{ gallons}: \quad 0.675 – (0.0015 \cdot \text{tank size})
  - For > 55 \text{ gallons}: \quad 0.8012 – (0.00078 \cdot \text{tank size})
  - If tank size unknown assume 40 gallons and \text{EF}_{\text{Baseline}} of 0.615

- \text{EF}_{\text{Efficient}} = \text{Energy Factor Rating for efficient equipment}
  - Actual. If Tankless whole-house multiply rated efficiency by 0.91\textsuperscript{531}. If unknown assume values in look up in table below

<table>
<thead>
<tr>
<th>Water Heater Type</th>
<th>\text{EF}_{\text{Efficient}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condensing Gas Storage</td>
<td>0.80</td>
</tr>
<tr>
<td>Gas Storage</td>
<td>0.67</td>
</tr>
<tr>
<td>Tankless whole-house</td>
<td>0.82 \cdot 0.91 = 0.75</td>
</tr>
</tbody>
</table>

- \text{EF}_{\text{Existing}} = \text{Energy Factor rating for existing equipment}
  - Use actual EF rating where it is possible to measure or reasonably estimate.
  - If unknown assume 0.52\textsuperscript{532}

- \text{GPD} = \text{Gallons Per Day of hot water use per person}
  - 45.5 gallons hot water per day per household/2.59 people per household\textsuperscript{533}
  - = 17.6

- \text{Household} = \text{Average number of people per household}

<table>
<thead>
<tr>
<th>Household Unit Type</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56\textsuperscript{534}</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1\textsuperscript{535}</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms\textsuperscript{536}</td>
</tr>
</tbody>
</table>

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

\textsuperscript{531} The disconnect between rated energy factor and in-situ energy consumption is markedly different for tankless units due to significantly higher contributions to overall household hot water usage from short draws. In tankless units the large burner and unit heat exchanger must fire and heat up for each draw. The additional energy losses incurred when the mass of the unit cools to the surrounding space in-between shorter draws was found to be 9% in a study prepared for Lawrence Berkeley National Laboratory by Davis Energy Group, 2006. “Field and Laboratory Testing of Tankless Gas Water Heater Performance” Due to the similarity (storage) between the other categories and the baseline, this derating factor is applied only to the tankless category.

\textsuperscript{532} Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.


\textsuperscript{536} Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
\[ \gamma_{\text{Water}} = \text{Specific Weight of water} = 8.33 \text{ pounds per gallon} \]

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

\[ T_{\text{IN}} = \text{Incoming water temperature from well or municipal system} = 54^\circ F \]

\[ 1.0 = \text{Heat Capacity of water (1 Btu/lb*°F)} \]

---

For example, a 40 gallon condensing gas storage water heater, with an energy factor of 0.80 in a single family house:

\[
\Delta \text{Therms} = \left( \frac{1}{0.615} - \frac{1}{0.8} \right) \times (17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1) / 100,000 \\
= 36.6 \text{ therms}
\]

---

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-HWE-GWHT-V07-180101

**REVIEW DEADLINE:** 1/1/2021

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5.4.3 Heat Pump Water Heaters

**DESCRIPTION**

The installation of a heat pump domestic hot water heater in place of a standard electric water heater in a home. Savings are presented dependent on the heating system installed in the home due to the impact of the heat pump water heater on the heating loads.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a Heat Pump domestic water heater.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is assumed to be a new electric water heater meeting federal minimum efficiency standards\(^{538}\):

\[
\text{For } \leq 55 \text{ gallons: } 0.96 - (0.0003 \times \text{rated volume in gallons}) \\
\text{For } > 55 \text{ gallons: } 2.057 - (0.00113 \times \text{rated volume in gallons})
\]

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 13 years\(^{539}\).

**DEEMED MEASURE COST**

The incremental capital cost for this measure is $1,000, for a HPWH with an energy factor of 2.0. The full cost, applicable in a retrofit, is $1,575. For a HPWH with an energy factor of 2.35, these costs are $1,134 and $1,703 respectively\(^{540}\).

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

The summer Peak Coincidence Factor is assumed to be 12\%\(^{541}\).

---


\(^{541}\) Calculated from Figure 8 “Combined six-unit summer weekday average electrical demand” in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf as (average kW usage during peak period \(\times \) hours in peak period) / [(annual kWh savings / FLH) \(\times \) hours in peak period] = \((0.1 \text{ kW} \times 5 \text{ hours}) / (2100 \text{ kWh (default assumptions)} / 2533 \text{ hours}) \times 5 \text{ hours}\) = 0.12
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \left( \frac{1}{\text{EF}_{\text{BASE}}} - \frac{1}{\text{EF}_{\text{EFFICIENT}}} \right) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 \div 3412 + \text{kWh}_{\text{cooling}} - \text{kWh}_{\text{heating}} \]

Where:

- \( \text{EF}_{\text{BASE}} \) = Energy Factor (efficiency) of standard electric water heater according to federal standards\(^{542}\):
  - For <=55 gallons: \( 0.96 - (0.0003 \times \text{rated volume in gallons}) \)
  - For >55 gallons: \( 2.057 - (0.00113 \times \text{rated volume in gallons}) \)
  - = 0.945 for a 50 gallon tank, the most common size for HPWH
- \( \text{EF}_{\text{EFFICIENT}} \) = Energy Factor (efficiency) of Heat Pump water heater
  = Actual
- \( \text{GPD} \) = Gallons Per Day of hot water use per person
  = 45.5 gallons hot water per day per household/2.59 people per household\(^{543}\)
  = 17.6
- \( \text{Household} \) = Average number of people per household

<table>
<thead>
<tr>
<th>Household Unit Type</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56(^{544})</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1(^{545})</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms(^{546})</td>
</tr>
</tbody>
</table>

- \( 365.25 \) = Days per year
- \( \gamma_{\text{Water}} \) = Specific weight of water
  = 8.33 pounds per gallon
- \( T_{\text{OUT}} \) = Tank temperature
  = 125°F
- \( T_{\text{IN}} \) = Incoming water temperature from well or municipal system


\(^{546}\) Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
\[
= 54^\circ F^{547}
\]

1.0

= Heat Capacity of water (1 Btu/lb*°F)

3412

= Conversion from Btu to kWh

\[
kWh\_cooling^{548} = \text{Cooling savings from conversion of heat in home to water heat}
\]

\[
=(((GPD \times \text{Household} \times 365.25 \times γ\text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412) -
((1/ EF_{\text{NEW}} \times GPD \times \text{Household} \times 365.25 \times γ\text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)) \times LF \times 27% / COP_{\text{COOL}} \times LM
\]

Where:

\[
LF
\]

= Location Factor

= 1.0 for HPWH installation in a conditioned space

= 0.5 for HPWH installation in an unknown location

= 0.0 for installation in an unconditioned space

27%

= Portion of reduced waste heat that results in cooling savings\(^{549}\)

\[
COP_{\text{COOL}}
\]

= COP of central air conditioning

= Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)

\[
LM
\]

= Latent multiplier to account for latent cooling demand

= 1.33 \(^{550}\)

\[
kWh\_heating
\]

= Heating cost from conversion of heat in home to water heat (dependent on heating fuel)

\[
=(((GPD \times \text{Household} \times 365.25 \times γ\text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412) -
((1/ EF_{\text{NEW}} \times GPD \times \text{Household} \times 365.25 \times γ\text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)) \times LF \times 49% / COP_{\text{HEAT}} \times (1 - %\text{NaturalGas})
\]

Where:

\[
49%
\]

= Portion of reduced waste heat that results in increased heating load\(^{551}\)

\[
COP_{\text{HEAT}}
\]

= COP of electric heating system

= actual. If not available use\(^{552}:\)


\(^{548}\) This algorithm calculates the heat removed from the air by subtracting the HPWH electric consumption from the total water heating energy delivered. This is then adjusted to account for location of the HP unit and the coincidence of the waste heat with cooling requirements, the efficiency of the central cooling and latent cooling demands.

\(^{549}\) REMRate determined percentage (27%) of lighting savings that result in reduced cooling loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

\(^{550}\) A sensible heat ratio (SHR) of 0.75 corresponds to a latent multiplier of 4/3 or 1.33. SHR of 0.75 for typical split system from page 10 of “Controlling Indoor Humidity Using Variable-Speed Compressors and Blowers” by M. A. Andrade and C. W. Bullard, 1999: www.ideals.illinois.edu/bitstream/handle/2142/11894/TR151.pdf

\(^{551}\) REMRate determined percentage (49%) of lighting savings that result in increased heating loads (lighting is used as a proxy for hot water heating since load shapes suggest their seasonal usage patterns are similar).

\(^{552}\) 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. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.
### Heat Pump Water Heaters

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP&lt;sub&gt;HEAT&lt;/sub&gt; (COP Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

**Calculation for COP Heat Pump Water Heaters**

\[
\text{COP}_{\text{HEAT}} = \frac{(\text{HSPF}/3.413) \times 0.85}{\text{HEAT}}
\]

For example, a 2.0 EF heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning (SEER 10.5) in Belleville:

\[
\Delta \text{kWh} = \left(\frac{1}{0.945} - \frac{1}{2.0}\right) \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) / 3412 + 166.3 - 0
\]

\[
= 1759 \text{ kWh}
\]

#### Summer Coincident Peak Demand Savings

\[
\Delta \text{kw} = \Delta \text{kWh} / \text{Hours} \times \text{CF}
\]

**Where:**

- Hours = Full load hours of water heater
  
  \[
  = 2533 \text{ 554}
  \]
- CF = Summer Peak Coincidence Factor for measure
  
  \[
  = 0.12 \text{ 555}
  \]

For example, a 2.0 COP heat pump water heater, in a conditioned space in a single family home with gas space heat and central air conditioning in Belleville:

\[
\text{kW} = 1759 / 2533 \times 0.12
\]

\[
= 0.083 \text{ kW}
\]

#### Natural Gas Savings

\[
\Delta \text{Therms} = \left((-(((\text{GPD} \times \text{Household} \times 365.25 \times \gamma \text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412) - (((\text{GPD} \times \text{Household} \times 365.25 \times \gamma \text{Water} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412) / \text{EFFICIENT}) \times \text{LF} \times 49\% \times 0.03412) / \eta_{\text{Heat}})ight)
\]

Where:

- \(\Delta \text{Therms}\) = Heating cost from conversion of heat in home to water heat for homes with Natural Gas

553 Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

554 Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

555 Calculated from Figure 8 "Combined six-unit summer weekday average electrical demand" in FEMP study; Field Testing of Pre-Production Prototype Residential Heat Pump Water Heaters [http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf](http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf) as (average kW usage during peak period * hours in peak period) / [(annual kWh savings / FLH) * hours in peak period] = (0.1 kW * 5 hours) / [(2100 kWh / 2533 hours) * 5 hours] = 0.12
heat.\textsuperscript{556} 
\begin{align*}
0.03412 &= \text{conversion factor (therms per kWh)} \\
\eta_{\text{Heat}} &= \text{Efficiency of heating system} \\
&= \text{Actual.}\textsuperscript{557} \text{If not available use 70%.}\textsuperscript{558} \\
\%_{\text{NaturalGas}} &= \text{Factor dependent on heating fuel:}
\end{align*}

<table>
<thead>
<tr>
<th>Heating System</th>
<th>%NaturalGas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric resistance or heat pump</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown heating fuel\textsuperscript{559}</td>
<td>87%</td>
</tr>
</tbody>
</table>

Other factors as defined above

For example, a 2.0 COP heat pump water heater in conditioned space, in a single family home with gas space heat (70% system efficiency):

\[
\Delta \text{Therms} = -(((17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1.0) / 3412) - (17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1.0 / 3412 / 2.0)) \times 1 \times 0.49 \times 0.03412) / (0.7 \times 1) = -34.1 \text{ therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-HWE-HPWH-V06-180101

**REVIEW DEADLINE:** 1/1/2021

\textsuperscript{556} This is the additional energy consumption required to replace the heat removed from the home during the heating season by the heat pump water heater. \text{kWh}_{\text{heating}} (electric resistance) is that additional heating energy for a home with electric resistance heat (COP 1.0). This formula converts the additional heating kWh for an electric resistance home to the MMBtu required in a Natural Gas heated home, applying the relative efficiencies.

\textsuperscript{557} 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.

\textsuperscript{558} This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (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)). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[(0.24\times 0.92) + (0.76\times 0.8) \times (1-0.15) = 0.70\]

\textsuperscript{559} 2010 American Community Survey.
5.4.4 Low Flow Faucet Aerators

DESCRIPTION
This measure relates to the installation of a low flow faucet aerator in a household kitchen or bath faucet fixture.

This measure may be used for units provided through Efficiency Kit’s however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, NC, RF, DI, KITS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be a low flow faucet aerator, for bathrooms rated at 1.5 gallons per minute (GPM) or less, or for kitchens rated at 2.2 GPM or less. Savings are calculated on an average savings per faucet fixture basis.

DEFINITION OF BASELINE EQUIPMENT
The baseline condition is assumed to be a standard bathroom faucet aerator rated at 2.25 GPM or greater, or a standard kitchen faucet aerator rated at 2.75 GPM or greater. Average measured flow rates are used in the algorithm and are lower, reflecting the penetration of previously installed low flow fixtures (and therefore the freerider rate for this measure should be 0), use of the faucet at less than full flow, debris buildup, and lower water system pressure than fixtures are rated at.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 9 years.\textsuperscript{560}

DEEMED MEASURE COST
For time of sale or new construction the incremental cost for this measure is $3\textsuperscript{561} or program actual.

For faucet aerators provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $8\textsuperscript{562} for Direct Install and $3 for Efficiency Kits.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR
The coincidence factor for this measure is assumed to be 2.2%.\textsuperscript{563}


\textsuperscript{561} 2011, Market research average of $3.

\textsuperscript{562} Includes assess and install labor time of $5 (20min @ $15/hr)

\textsuperscript{563} Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% * 180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022
Algorithm

Calculation of Savings

Electric Energy Savings

Note these savings are per faucet retrofitted (unless faucet type is unknown, then it is per household).

\[ \Delta \text{kWh} = \% \text{ElectricDHW} \times \left( (\text{GPM}_{\text{base}} \times \text{L}_{\text{base}} - \text{GPM}_{\text{low}} \times \text{L}_{\text{low}}) \times \text{Household} \times 365.25 \times \text{DF} / \text{FPH} \right) \times \text{EPG}_{\text{electric}} \times \text{ISR} \]

Where:

\[ \% \text{ElectricDHW} = \text{proportion of water heating supplied by electric resistance heating} \]

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%ElectricDHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>16%</td>
</tr>
</tbody>
</table>

\[ \text{GPM}_{\text{base}} = \text{Average flow rate, in gallons per minute, of the baseline faucet “as-used.” This includes the effect of existing low flow fixtures and therefore the freerider rate for this measure should be 0.} \]

\[ = 1.39 \text{ or custom based on metering studies or if measured during DI:} \]

\[ = \text{Measured full throttle flow} \times 0.83 \text{ throttling factor} \]

\[ \text{GPM}_{\text{low}} = \text{Average flow rate, in gallons per minute, of the low-flow faucet aerator “as-used”} \]

\[ = 0.94 \text{ or custom based on metering studies or if measured during DI:} \]

\[ = \text{Rated full throttle flow} \times 0.95 \text{ throttling factor} \]

---

564 This algorithm calculates the amount of energy saved per aerator by determining the fraction of water consumption savings for the upgraded fixture.

565 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.


567 Measurement should be based on actual average flow consumed over a period of time rather than a one-time spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.


569 Average retrofit flow rate for kitchen and bathroom faucet aerators from sources 2, 4, 5, and 7 (see source table at end of characterization). This accounts for all throttling and differences from rated flow rates. Assumes all kitchen aerators at 2.2 gpm or less and all bathroom aerators at 1.5 gpm or less. The most comprehensive available studies did not disaggregate kitchen use from bathroom use, but instead looked at total flow and length of use for all faucets. This makes it difficult to reliably separate kitchen water use from bathroom water use. It is possible that programs installing low flow aerators lower than the 2.2 gpm for kitchens and 1.5 gpm for bathrooms will see a lower overall average retrofit flow rate.

570 Measurement should be based on actual average flow consumed over a period of time rather than a one-time spot measurement for maximum flow. Studies have shown maximum flow rates do not correspond well to average flow rate due to occupant behavior which does not always use maximum flow.

L_base = Average baseline daily length faucet use per capita for faucet of interest in minutes
       = if available custom based on metering studies, if not use:

<table>
<thead>
<tr>
<th>Faucet Type</th>
<th>L_base (min/person/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>4.5572</td>
</tr>
<tr>
<td>Bathroom</td>
<td>1.6573</td>
</tr>
<tr>
<td>If location unknown (total for household): Single-Family</td>
<td>9.0574</td>
</tr>
<tr>
<td>If location unknown (total for household): Multi-Family</td>
<td>6.9575</td>
</tr>
</tbody>
</table>

L_low = Average retrofit daily length faucet use per capita for faucet of interest in minutes
       = if available custom based on metering studies, if not use:

<table>
<thead>
<tr>
<th>Faucet Type</th>
<th>L_low (min/person/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>4.5576</td>
</tr>
<tr>
<td>Bathroom</td>
<td>1.6577</td>
</tr>
<tr>
<td>If location unknown (total for household): Single-Family</td>
<td>9.0578</td>
</tr>
<tr>
<td>If location unknown (total for household): Multi-Family</td>
<td>6.9579</td>
</tr>
</tbody>
</table>

Household = Average number of people per household

<table>
<thead>
<tr>
<th>Household Unit Type</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56580</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1581</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms582</td>
</tr>
</tbody>
</table>

572 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.
573 Ibid.
574 One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
575 One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
577 Ibid.
578 One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
579 One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
582 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
365.25 = Days in a year, on average.

DF = Drain Factor

<table>
<thead>
<tr>
<th>Faucet Type</th>
<th>Drain Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen</td>
<td>75%</td>
</tr>
<tr>
<td>Bath</td>
<td>90%</td>
</tr>
<tr>
<td>Unknown</td>
<td>79.5%</td>
</tr>
</tbody>
</table>

FPH = Faucets Per Household

<table>
<thead>
<tr>
<th>FPH</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen Faucets Per Home (KFPH)</td>
<td>0</td>
</tr>
<tr>
<td>Bathroom Faucets Per Home (BFPH): Single-Family</td>
<td>1</td>
</tr>
<tr>
<td>Bathroom Faucets Per Home (BFPH): Multi-Family</td>
<td>2.83</td>
</tr>
<tr>
<td>If location unknown (total for household): Single-Family</td>
<td>1.5</td>
</tr>
<tr>
<td>If location unknown (total for household): Multi-Family</td>
<td>3.83</td>
</tr>
</tbody>
</table>

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater

\[ EPG_{electric} = \frac{(8.33 \times 1.0 \times (\text{WaterTemp} - \text{SupplyTemp}))}{(\text{RE}_{electric} \times 3412)} \]

\[ = \frac{(8.33 \times 1.0 \times (86 - 54.1))}{(0.98 \times 3412)} \]

\[ = 0.0795 \text{ kWh/gal (Bath), 0.0969 kWh/gal (Kitchen), 0.0919 kWh/gal (Unknown)} \]

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb·°F)

WaterTemp = Assumed temperature of mixed water

\[ = 86°F \text{ for Bath, 93°F for Kitchen 91°F for Unknown} \]

SupplyTemp = Assumed temperature of water entering house

\[ = 54.1°F \]

RE_{electric} = Recovery efficiency of electric water heater

583 Because faucet usages are at times dictated by volume, only usage of the sort that would go straight down the drain will provide savings. VEIC is unaware of any metering study that has determined this specific factor and so through consensus with the Illinois Technical Advisory Group have deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7\times0.75)+(0.3\times0.9)=0.795.

584 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

585 Ibid.

586 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. If the aerator location is unknown an average of 91% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom (0.7\times0.93)+(0.3\times0.86)=0.91.

= 98%  

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of faucet aerators dependant on install method as listed in table below

<table>
<thead>
<tr>
<th>Selection</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install - Single Family</td>
<td>0.95</td>
</tr>
<tr>
<td>Direct Install – Multi Family Kitchen</td>
<td>0.91</td>
</tr>
<tr>
<td>Direct Install – Multi Family Bathroom</td>
<td>0.95</td>
</tr>
<tr>
<td>Efficiency Kit Bathroom Aerator</td>
<td>0.63</td>
</tr>
<tr>
<td>Efficiency Kit Kitchen Aerator</td>
<td>0.60</td>
</tr>
<tr>
<td>Distributed School Efficiency Kit Aerator</td>
<td>To be determined through evaluation</td>
</tr>
</tbody>
</table>

For example, a direct installed kitchen low flow faucet aerator in a single-family electric DHW home:

\[
\Delta kWh = 1.0 \times \frac{((1.39 \times 4.5 - 0.94 \times 4.5) \times 2.56 \times 365.25 \times 0.75)}{1} \times 0.0969 \times 0.95
\]

\[
\Delta kWh = 131 \text{ kWh}
\]

For example, a direct installed bath low flow faucet aerator in a multi-family electric DHW home:

\[
\Delta kWh = 1.0 \times \frac{((1.39 \times 1.6 - 0.94 \times 1.6) \times 2.1 \times 365.25 \times 0.90)}{1.5} \times 0.0795 \times 0.95
\]

\[
\Delta kWh = 25.0 \text{ kWh}
\]

For example, a direct installed low flow faucet aerator in unknown faucet in a single-family electric DHW home:

\[
\Delta kWh = 1.0 \times \frac{((1.39 \times 9.0 - 0.94 \times 9.0) \times 2.56 \times 365.25 \times 0.795)}{3.83} \times 0.0919 \times 0.95
\]

\[
\Delta kWh = 68.6 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \frac{\Delta kWh}{\text{Hours} \times \text{CF}}
\]

Where:

---

588 Electric water heaters have recovery efficiency of 98%: [http://www.ahridirectory.org/ahridirectory/pages/home.aspx](http://www.ahridirectory.org/ahridirectory/pages/home.aspx)


591 Ibid.


593 Ibid.
ΔkWh = calculated value above

Hours = Annual electric DHW recovery hours for faucet use per faucet

\[
\text{Hours per faucet} = \frac{(\text{GPM}_\text{base} \times \text{L}_\text{base}) \times \text{Household/PH} \times 365.25 \times \text{DF} \times 0.545}{\text{GPH}}
\]

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Faucet location</th>
<th>Calculation</th>
<th>Hours per faucet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Family</td>
<td>Kitchen</td>
<td>((1.39 * 4.5) * 2.56/1 * 365.25 * 0.75) * 0.545 / 25.5</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Bathroom</td>
<td>((1.39 * 1.6) * 2.56/2.83 * 365.25 * 0.9) * 0.545 / 25.5</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>((1.39 * 9.0) * 2.56/3.83 * 365.25 * 0.795) * 0.545 / 25.5</td>
<td>52</td>
</tr>
<tr>
<td>Multi Family</td>
<td>Kitchen</td>
<td>((1.39 * 4.5) * 2.1/1 * 365.25 * 0.75) * 0.545 / 25.5</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Bathroom</td>
<td>((1.39 * 1.6) * 2.1/1.5 * 365.25 * 0.9) * 0.545 / 25.5</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>((1.39 * 6.9) * 2.1/2.5 * 365.25 * 0.795) * 0.545 / 25.5</td>
<td>50</td>
</tr>
</tbody>
</table>

GPH = Gallons per hour recovery of electric water heater calculated for 70.9°F temp rise (125-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

CF = Coincidence Factor for electric load reduction

\[\text{CF} = 0.022\]  

For example, a direct installed kitchen low flow faucet aerator in a single family electric DHW home:

\[
\Delta k\text{W} = \frac{131}{94} \times 0.022 = 0.0306 \text{ kW}
\]

### NATURAL GAS SAVINGS

\[
\Delta \text{Therms} = \%\text{FossilDHW} \times \left((\text{GPM}_\text{base} \times \text{L}_\text{base} - \text{GPM}_\text{low} \times \text{L}_\text{low}) \times \text{Household} \times 365.25 \times \text{DF} / \text{FPH}\right) \times \text{EPG}_\text{gas} \times \text{ISR}
\]

Where:

\[
\%\text{FossilDHW} = \text{proportion of water heating supplied by Natural Gas heating}
\]

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Fossil_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>84%</td>
</tr>
</tbody>
</table>

| EPG_gas      | = Energy per gallon of Hot water supplied by gas |

---

54.5% is the proportion of hot 120°F water mixed with 54.1°F supply water to give 90°F mixed faucet water.

594 Calculated as follows: Assume 18% aerator use takes place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.) There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.18*65/365 = 3.21%. The number of hours of recovery during peak periods is therefore assumed to be 3.21% * 180 = 5.8 hours of recovery during peak period where 180 equals the average annual electric DHW recovery hours for faucet use including SF and MF homes. There are 260 hours in the peak period so the probability you will see savings during the peak period is 5.8/260 = 0.022

595 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.
\[
\Delta \text{gallons} = \left( \frac{(8.33 \times 1.0 \times (\text{WaterTemp} - \text{SupplyTemp}))}{\text{RE}_{\text{gas}} \times 100,000} \right) \\
= 0.00341 \text{ Therm/gal for SF homes (Bath), 0.00415 Therm/gal for SF homes (Kitchen), 0.00394 Therm/gal for SF homes (Unknown)} \\
= 0.00397 \text{ Therm/gal for MF homes (Bath), 0.00484 Therm/gal for MF homes (Kitchen), 0.00459 Therm/gal for MF homes (Unknown)} \\
\]

\text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater} \\
\text{= 78\% for SF homes}^{597} \\
\text{= 67\% for MF homes}^{598} \\
100,000 = \text{Converts Btus to Therms (btu/Therm)} \\
\text{Other variables as defined above.}

For example, a direct-installed kitchen low flow faucet aerator in a fuel DHW single-family home:
\[
\Delta \text{Therms} = 1.0 \times \left( \frac{((1.39 \times 4.5 - 0.94 \times 4.5) \times 2.56 \times 365.25 \times 0.75)}{1} \times 0.00415 \times 0.95 \right) \\
= 5.60 \text{ Therms}
\]

For example, a direct installed bath low flow faucet aerator in a fuel DHW multi-family home:
\[
\Delta \text{Therms} = 1.0 \times \left( \frac{((1.39 \times 1.6 - 0.94 \times 1.6) \times 2.1 \times 365.25 \times 0.90)}{1.5} \times 0.003974 \times 0.95 \right) \\
= 1.25 \text{ Therms}
\]

For example, a direct installed low flow faucet aerator in unknown faucet in a fuel DHW single-family home:
\[
\Delta \text{Therms} = 1.0 \times \left( \frac{((1.39 \times 9.0 - 0.94 \times 9.0) \times 2.56 \times 365.25 \times 0.795)}{3.83} \times 0.00394 \times 0.95 \right) \\
= 2.94 \text{ Therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[
\Delta \text{gallons} = \left( \text{GPM}_{\text{base}} \times \text{L}_{\text{base}} - \text{GPM}_{\text{low}} \times \text{L}_{\text{low}} \right) \times \text{Household} \times 365.25 \times \text{DF} / \text{FPH} \times \text{ISR} \\
\text{Variables as defined above}
\]

---

597 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 78%.

598 Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.
For example, a direct-installed kitchen low flow aerator in a single family home:

$$\Delta \text{gallons} = \frac{((1.39 \times 4.5 - 0.94 \times 4.5) \times 2.56 \times 365.25 \times 0.75)}{1} \times 0.95$$

$$= 1350 \text{ gallons}$$

For example, a direct installed bath low flow faucet aerator in a multi-family home:

$$\Delta \text{gallons} = \frac{((1.39 \times 1.6 - 0.94 \times 1.6) \times 2.1 \times 365.25 \times 0.90)}{1.5} \times 0.95$$

$$= 314 \text{ gallons}$$

For example, a direct installed low flow faucet aerator in unknown faucet in a single-family home:

$$\Delta \text{gallons} = \frac{((1.39 \times 9.0 - 0.94 \times 9.0) \times 2.56 \times 365.25 \times 0.795)}{3.83} \times 0.95$$

$$= 747 \text{ gallons}$$

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES**

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Reference</th>
</tr>
</thead>
</table>

**MEASURE CODE: RS-HWE-LFFA-V06-180101**

**REVIEW DEADLINE: 1/1/2021**
5.4.5 Low Flow Showerheads

**DESCRIPTION**

This measure relates to the installation of a low flow showerhead in a single or multi-family household.

This measure may be used for units provided through Efficiency Kit’s however the in service rate for such measures should be derived through evaluation results specifically for this implementation methodology.

This measure was developed to be applicable to the following program types: TOS, RF, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be a low flow showerhead rated at 2.0 gallons per minute (GPM) or less. Savings are calculated on a per showerhead fixture basis.

**DEFINITION OF BASELINE EQUIPMENT**

For Direct-install programs, the baseline condition is assumed to be a standard showerhead rated at 2.5 GPM or greater.

For retrofit and time-of-sale programs, the baseline condition is assumed to be a representative average of existing showerhead flow rates of participating customers including a range of low flow showerheads, standard-flow showerheads, and high-flow showerheads.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 10 years.  

**DEEMED MEASURE COST**

For time of sale or new construction the incremental cost for this measure is $7600 or program actual.

For low flow showerheads provided through Direct Install or within Efficiency Kits, the actual program delivery costs (including labor if applicable) should be utilized. If unknown assume $12601 for Direct Install and $7 for Efficiency Kits.

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

The coincidence factor for this measure is assumed to be 2.78%.  

---

599 Table C-6, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. Evaluations indicate that consumer dissatisfaction may lead to reductions in persistence, particularly in Multi-Family, "http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf"

600 Market research average of $7.

601 Includes assess and install labor time of $5 (20min @ $15/hr)

602 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278
Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Note these savings are per showerhead fixture

\[ \Delta \text{kWh} = \% \text{ElectricDHW} \times ((\text{GPM}_{\text{base}} \times L_{\text{base}} - \text{GPM}_{\text{low}} \times L_{\text{low}}) \times \text{Household} \times SPCD \times 365.25 \div \text{SPH}) \times \text{EPG}_{\text{electric}} \times \text{ISR} \]

Where:

\( \% \text{ElectricDHW} \) = proportion of water heating supplied by electric resistance heating

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%ElectricDHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>16%603</td>
</tr>
</tbody>
</table>

\( \text{GPM}_{\text{base}} \) = Flow rate of the baseline showerhead

<table>
<thead>
<tr>
<th>Program</th>
<th>GPM_{base}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct-install</td>
<td>2.67604</td>
</tr>
<tr>
<td>Retrofit, Efficiency Kits, NC or TOS</td>
<td>2.35605</td>
</tr>
</tbody>
</table>

\( \text{GPM}_{\text{low}} \) = As-used flow rate of the low-flow showerhead, which may, as a result of measurements of program evaluations deviate from rated flows, see table below:

<table>
<thead>
<tr>
<th>Rated Flow</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 GPM</td>
<td></td>
</tr>
<tr>
<td>1.75 GPM</td>
<td></td>
</tr>
<tr>
<td>1.5 GPM</td>
<td></td>
</tr>
<tr>
<td>Custom or Actual606</td>
<td></td>
</tr>
</tbody>
</table>

\( L_{\text{base}} \) = Shower length in minutes with baseline showerhead

\[ = 7.8 \text{ min}607 \]

603 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

604 Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above.

605 Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.

606 Note that actual values may be either a) program-specific minimum flow rate, or b) program-specific evaluation-based value of actual effective flow-rate due to increased duration or temperatures. The latter increases in likelihood as the rated flow drops and may become significant at or below rated flows of 1.5 GPM. The impact can be viewed as the inverse of the throttling described in the footnote for baseline flowrate.

607 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters
L_low = Shower length in minutes with low-flow showerhead
       = 7.8 min\(^608\)

Household = Average number of people per household

<table>
<thead>
<tr>
<th>Household Unit Type(^609)</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56(^610)</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1(^611)</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms(^612)</td>
</tr>
</tbody>
</table>

SPCD = Showers Per Capita Per Day
       = 0.6\(^613\)

365.25 = Days per year, on average.

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

<table>
<thead>
<tr>
<th>Household Type</th>
<th>SPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>1.79(^614)</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>1.3(^615)</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual</td>
</tr>
</tbody>
</table>

EPG_electric = Energy per gallon of hot water supplied by electric
               = \((8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_\text{electric} \times 3412)\)
               = \((8.33 \times 1.0 \times (101 - 54.1)) / (0.98 \times 3412)\)
               = 0.117 kWh/gal

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb\(^\circ\)F)

ShowerTemp = Assumed temperature of water
             = 101\(^616\)F

for efficient showerhead and faucet aerators.

\(^{608}\) Ibid.

\(^{609}\) If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.


\(^{611}\) ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx

\(^{612}\) Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.


\(^{614}\) Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

\(^{615}\) Ibid.

SupplyTemp = Assumed temperature of water entering house
= 54.1F

RE_electric = Recovery efficiency of electric water heater
= 98%

3412 = Converts Btu to kWh (btu/kWh)

ISR = In service rate of showerhead
Dependant on program delivery method as listed in table below

<table>
<thead>
<tr>
<th>Selection</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install - Single Family</td>
<td>0.98619</td>
</tr>
<tr>
<td>Direct Install – Multi Family</td>
<td>0.95620</td>
</tr>
<tr>
<td>Efficiency Kits--One showerhead kit</td>
<td>0.65621</td>
</tr>
<tr>
<td>Efficiency Kits—Two showerhead kit</td>
<td>0.67622</td>
</tr>
<tr>
<td>Distributed School Efficiency Kit showerhead</td>
<td>To be determined through evaluation</td>
</tr>
</tbody>
</table>

For example, a direct-installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

\[
\Delta kWh = 1.0 \times ((2.67 \times 7.8 - 1.5 \times 7.8) \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.117 \times 0.98
\]

= 328 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \Delta kWh / Hours \times CF
\]

Where:

\[
\Delta kWh = \text{calculated value above}
\]

Hours = Annual electric DHW recovery hours for showerhead use

\[
= \left( \frac{\text{GPM}_{\text{base}} \times \text{L}_{\text{base}} \times \text{Household} \times \text{SPCD} \times 365.25}{\text{GPH}} \right) \times 0.712623
\]

= 302 for SF Direct Install; 248 for MF Direct Install

= 266 for SF Retrofit, Efficiency Kits, NC and TOS; 218 for MF Retrofit, Efficiency Kits, NC and TOS

GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

---


622 Ibid

623 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.
For example, a direct installed 1.5 GPM low flow showerhead in a single family home with electric DHW where the number of showers is not known:

\[
\Delta kW = \frac{328}{302} \times 0.0278 = 0.0302 \text{ kW}
\]

**Natural Gas Savings**

\[
\Delta \text{Therms} = \%\text{FossilDHW} \times \left( (\text{GPM}_{\text{base}} \times \text{L}_{\text{base}} - \text{GPM}_{\text{low}} \times \text{L}_{\text{low}}) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH} \right) \times \text{EPG}_{\text{gas}} \times \text{ISR}
\]

Where:

- \%\text{FossilDHW} = \text{proportion of water heating supplied by Natural Gas heating}
- \text{EPG}_{\text{gas}} = \text{Energy per gallon of Hot water supplied by gas}
  \[
  \text{EPG}_{\text{gas}} = \frac{(8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp}))}{(\text{RE}_{\text{gas}} \times 100,000)}
  \]
  - For SF homes: 0.00501 Therm/gal
  - For MF homes: 0.00583 Therm/gal
- \text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater}
  \[
  \text{RE}_{\text{gas}} = \frac{78}{100} \% \text{ For SF homes}^{625}
  \]
  - For MF homes: 67%

\[
\text{DHW fuel} \quad \%\text{Fossil}_\text{DHW}
\]

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Fossil_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>84%^{625}</td>
</tr>
</tbody>
</table>

\[
\text{Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.}
\]

\[
\text{DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87%. Average of existing units is estimated at 78%.}
\]

\[
\text{Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.}
\]
100,000 = Converts Btus to Therms (btu/Therm)
Other variables as defined above.

For example, a direct installed 1.5 GPM low flow showerhead in a gas fired DHW single family home where the number of showers is not known:

\[
\Delta\text{Therms} = 1.0 \times ((2.67 \times 7.8 - 1.5 \times 7.8) \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.00501 \times 0.98
\]
\[
= 14.0 \text{ therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[
\Delta\text{gallons} = ((GPM\_base \times L\_base - GPM\_low \times L\_low) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH}) \times \text{ISR}
\]
Variables as defined above

For example, a direct installed 1.5 GPM low flow showerhead in a single family home where the number of showers is not known:

\[
\Delta\text{gallons} = ((2.67 \times 7.8 - 1.5 \times 7.8) \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.98
\]
\[
= 2803 \text{ gallons}
\]

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**SOURCES**

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Reference</th>
</tr>
</thead>
</table>

**MEASURE CODE: RS-HWE-LFSH-V05-180101**

**REVIEW DEADLINE: 1/1/2023**
5.4.6 Water Heater Temperature Setback

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

**DEFINITION OF EFFICIENT EQUIPMENT**
High efficiency is a hot water tank with the thermostat reduced to no lower than 120 degrees.

**DEFINITION OF BASELINE EQUIPMENT**
The baseline condition is a hot water tank with a thermostat setting that is higher than 120 degrees, typically systems with settings of 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.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**
The assumed lifetime of the measure is 2 years.

**DEEMED MEASURE COST**
The incremental cost of a setback is assumed to be $5 for contractor time, or no cost if the measure is self-installed.

**LOADSHAPE**
Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**
The summer peak coincidence factor for this measure is assumed to be 1.

---

### Algorithm

#### ELECTRIC ENERGY SAVINGS

For homes with electric DHW tanks:

\[
\Delta k\text{Wh}^{628} = \frac{(U \times A \times (T_{pre} - T_{post}) \times \text{Hours} \times \text{ISR})}{(3412 \times \text{RE}_{\text{electric}})}
\]

Where:

- \(U\) = Overall heat transfer coefficient of tank (Btu/Hr·°F·ft²).
- \(U\) = Actual if known. If unknown assume R-12, \(U = 0.083\)
- \(A\) = Surface area of storage tank (square feet)

---

628 Note this algorithm provides savings only from reduction in standby losses. The TAC considered avoided energy from not heating the water to the higher temperature but determined that 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. It was felt the potential impact was too small to be characterized.
= Actual if known. If unknown use table below based on capacity of tank. If capacity unknown assume 50 gal tank; A = 24.99ft²

<table>
<thead>
<tr>
<th>Capacity (gal)</th>
<th>A (ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>19.16</td>
</tr>
<tr>
<td>40</td>
<td>23.18</td>
</tr>
<tr>
<td>50</td>
<td>24.99</td>
</tr>
<tr>
<td>80</td>
<td>31.84</td>
</tr>
</tbody>
</table>

Tpre = Actual hot water setpoint prior to adjustment
Tpost = Actual new hot water setpoint, which may not be lower than 120 degrees

Default Hot Water Temperature Inputs

<table>
<thead>
<tr>
<th>Tpre</th>
<th>135</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tpost</td>
<td>120</td>
</tr>
</tbody>
</table>

Hours = Number of hours in a year (since savings are assumed to be constant over year).
= 8766

ISR = In service rate of measure
= Dependant on program delivery method as listed in table below

<table>
<thead>
<tr>
<th>Delivery method</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructions provided in a Kit</td>
<td>To be determined through evaluation</td>
</tr>
<tr>
<td>All other</td>
<td>1.0</td>
</tr>
</tbody>
</table>

3412 = Conversion from Btu to kWh
RE_electric = Recovery efficiency of electric hot water heater
= 0.98

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

ΔkWh = (U * A * (Tpre – Tpost) * Hours * ISR) / (3412 * RE_electric)
= (((0.083 * 24.99) * (135 – 120) * 8766 * 1.0) / (3412 * 0.98)
= 81.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

ΔkW = ΔkWh / Hours * CF

Where:

Hours = 8766
CF = Summer Peak Coincidence Factor for measure
= 1

---

629 Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation.

630 Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
A deemed savings assumption, where site specific assumptions are not available would be as follows:

\[
\Delta kW = \left(\frac{81.6}{8766}\right) \times 1
\]

\[
\Delta kW \text{ default} = 0.00931 \text{ kW}
\]

**Natural Gas Savings**

For homes with gas water heaters:

\[
\Delta \text{Therms} = \left( U \times A \times (T_{\text{pre}} - T_{\text{post}}) \times \text{Hours} \times \text{ISR} \right) / \left( 100,000 \times \text{RE}_{\text{gas}} \right)
\]

Where

- 100,000 = Converts Btus to Therms (btu/Therm)
- RE\_gas = Recovery efficiency of gas water heater
  - 78% For SF homes\(^{631}\)
  - 67% For MF homes\(^{632}\)

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

For Single Family homes:

\[
\Delta \text{Therms} = \left( U \times A \times (T_{\text{pre}} - T_{\text{post}}) \times \text{Hours} \times \text{ISR} \right) / \text{RE}_{\text{gas}}
\]

\[
= \left( ((0.083 \times 24.99) \times (135 - 120) \times 8766 \times 1.0) / (100,000 \times 0.78) \right)
\]

\[
= 3.5 \text{ Therms}
\]

For Multi Family homes:

\[
\Delta \text{Therms} = \left( U \times A \times (T_{\text{pre}} - T_{\text{post}}) \times \text{Hours} \times \text{ISR} \right) / \text{RE}_{\text{gas}}
\]

\[
= \left( ((0.083 \times 24.99) \times (135 - 120) \times 8766 \times 1.0) / (100,000 \times 0.67) \right)
\]

\[
= 4.1 \text{ Therms}
\]

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code:** RS-HWE-TMPS-V05-160601

**Review Deadline:** 1/1/2022

\(^{631}\) 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 78%.

\(^{632}\) Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.
5.4.7 Water Heater Wrap

**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. Generally this can be determined based upon the appearance of the tank.\(^{633}\)

This measure was developed to be applicable to the following program types: RF, DI.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The measure is a properly installed, R-8 or greater insulating tank wrap to reduce standby energy losses from the tank to the surrounding ambient area.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is a standard electric domestic hot water tank without an additional tank wrap. Gas storage water heaters are excluded due to the limitations of retrofit wrapping and the associated impacts on reduced savings and safety.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The measure life is assumed to be 5 years\(^{634}\).

**DEEMED MEASURE COST**

The incremental cost for this measure will be the actual material cost of procuring and labor cost of installing the tank wrap.

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

This measure assumes a flat loadshape and as such the coincidence factor is 1.

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

For electric DHW systems:

\[
\Delta \text{kWh} = \left( \frac{A_{\text{base}}}{R_{\text{base}}} - \frac{A_{\text{insul}}}{R_{\text{insul}}} \right) \cdot \Delta T \cdot \text{Hours} / (3412 \cdot \eta_{\text{DHW}})
\]

Where:

\(^{633}\) Visually determine whether it is insulated by foam (newer, rigid, and more effective) or fiberglass (older, gives to gently pressure, and not as effective)

\(^{634}\) This estimate assumes the tank wrap is installed on an existing unit with 5 years remaining life.
\[ R_{\text{base}} = \text{Overall thermal resistance coefficient prior to adding tank wrap (Hr}-\text{°F}-\text{ft}^2/\text{BTU}). \]
\[ R_{\text{insul}} = \text{Overall thermal resistance coefficient after addition of tank wrap (Hr}-\text{°F}-\text{ft}^2/\text{BTU}). \]
\[ A_{\text{base}} = \text{Surface area of storage tank prior to adding tank wrap (square feet)}^{635} \]
\[ A_{\text{insul}} = \text{Surface area of storage tank after addition of tank wrap (square feet)}^{636} \]
\[ \Delta T = \text{Average temperature difference between tank water and outside air temperature (°F)}^{637} = 60°\text{F} \]
\[ \text{Hours} = \text{Number of hours in a year (since savings are assumed to be constant over year).} = 8766 \]
\[ 3412 = \text{Conversion from Btu to kWh} \]
\[ \eta_{\text{DHW}} = \text{Recovery efficiency of electric hot water heater} = 0.98^{638} \]

The following table has default savings for various tank capacity and pre and post R-VALUES.

<table>
<thead>
<tr>
<th>Capacity (gal)</th>
<th>Rbase</th>
<th>Rinsul</th>
<th>Abase (ft²)(^639)</th>
<th>Ainsul (ft²)(^640)</th>
<th>ΔkWh</th>
<th>ΔkW</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>8</td>
<td>16</td>
<td>19.16</td>
<td>20.94</td>
<td>171</td>
<td>0.0195</td>
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<tr>
<td>30</td>
<td>10</td>
<td>18</td>
<td>19.16</td>
<td>20.94</td>
<td>118</td>
<td>0.0135</td>
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<td>30</td>
<td>12</td>
<td>20</td>
<td>19.16</td>
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<td>30</td>
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<td>18</td>
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<td>20.94</td>
<td>194</td>
<td>0.0221</td>
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<tr>
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<td>20</td>
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<td>20.94</td>
<td>137</td>
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<tr>
<td>30</td>
<td>12</td>
<td>22</td>
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<td>20.94</td>
<td>101</td>
<td>0.0116</td>
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<td>40</td>
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<td>18</td>
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<td>34.14</td>
<td>290</td>
<td>0.0331</td>
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<td>10</td>
<td>18</td>
<td>31.84</td>
<td>34.14</td>
<td>202</td>
<td>0.0231</td>
</tr>
<tr>
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<td>12</td>
<td>20</td>
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<td>34.14</td>
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<td>0.0170</td>
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<td>34.14</td>
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<td>0.0374</td>
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<td>20</td>
<td>31.84</td>
<td>34.14</td>
<td>232</td>
<td>0.0265</td>
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<tr>
<td>80</td>
<td>12</td>
<td>22</td>
<td>31.84</td>
<td>34.14</td>
<td>173</td>
<td>0.0198</td>
</tr>
</tbody>
</table>

\(^{635}\) Area includes tank sides and top to account for typical wrap coverage.

\(^{636}\) Ibid.

\(^{637}\) Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

\(^{638}\) Electric water heaters have recovery efficiency of 98%: [http://www.ahridirectory.org/ahridirectory/pages/home.aspx](http://www.ahridirectory.org/ahridirectory/pages/home.aspx)

\(^{639}\) Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

\(^{640}\) Assumptions from PA TRM. \(A_{\text{insul}}\) was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kWh / 8766 \times CF \]

Where:
- \( \Delta kWh \) = kWh savings from tank wrap installation
- 8766 = Number of hours in a year (since savings are assumed to be constant over year).
- CF = Summer Coincidence Factor for this measure = 1.0

The table above has default kW savings for various tank capacity and pre and post R-values.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-HWE-WRAP-V02-150601**

**REVIEW DEADLINE: 1/1/2022**
5.4.8 Thermostatic Restrictor Shower Valve

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 95°F 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 EFFICIENT EQUIPMENT
To qualify for this measure the installed equipment must be a thermostatic restrictor shower valve installed on a residential showerhead.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is the residential showerhead without the restrictor valve installed.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The expected measure life is assumed to be 10 years.\(^{641}\)

DEEMED MEASURE COST
The incremental cost of the measure should be the actual program cost (including labor if applicable) or $30\(^{642}\) plus $20 labor\(^{643}\) if not available.

LOADSHAPE
Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR
The coincidence factor for this measure is assumed to be 0.22%.\(^{644}\)

---


\(^{642}\) Based on actual cost of the SS-1002CP-SB Ladybug Water-Saving Shower-Head adapter from Evolve showerheads.

\(^{643}\) Estimate for contractor installation time.

\(^{644}\) Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022.
Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta k\text{Wh} = \%\text{ElectricDHW} \times (\text{GPM}_{\text{base}} \times L_{\text{showerdevice}}) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH} \times \text{EPG}_{\text{electric}} \times \text{ISR} \]

Where:

- \( \%\text{ElectricDHW} \) = proportion of water heating supplied by electric resistance heating
- \( \text{GPM}_{\text{base}} \) = Flow rate of the basecase showerhead, or actual if available
- \( L_{\text{showerdevice}} \) = Hot water waste time avoided due to thermostatic restrictor valve
  - \( 0.89 \) minutes\(^648\)
- \( \text{Household} \) = Average number of people per household

### Table: DHW fuel vs. \%ElectricDHW

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%ElectricDHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>16%(^645)</td>
</tr>
</tbody>
</table>

### Table: Program GPM

<table>
<thead>
<tr>
<th>Program</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct-install, device only</td>
<td>2.67(^646)</td>
</tr>
<tr>
<td>New Construction or direct install of device and low flow showerhead</td>
<td>Rated or actual flow of program-installed showerhead</td>
</tr>
<tr>
<td>Retrofit or TOS</td>
<td>2.35(^647)</td>
</tr>
</tbody>
</table>

- \( L_{\text{showerdevice}} \) = 0.89 minutes\(^648\)
- \( \text{Household} \) = Average number of people per household

### Table: Household Unit Type

<table>
<thead>
<tr>
<th>Household Unit Type</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56(^650)</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1(^651)</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms(^652)</td>
</tr>
</tbody>
</table>

\(^645\) Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

\(^646\) Based on measured data from Ameren IL EM&V of Direct-Install program. Program targets showers that are rated 2.5 GPM or above. Assumes low flow showerhead not included in direct installation.

\(^647\) Representative value from sources 1, 2, 4, 5, 6 and 7 (See Source Table at end of measure section) adjusted slightly upward to account for program participation which is expected to target customers with existing higher flow devices rather than those with existing low flow devices.


\(^649\) If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.


\(^651\) ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx

\(^652\) Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.
SPCD  = Showers Per Capita Per Day
      = 0.6653

365.25 = Days per year, on average.

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

<table>
<thead>
<tr>
<th>Household Type</th>
<th>SPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>1.79654</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>1.3655</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual</td>
</tr>
</tbody>
</table>

EPG_electric  = Energy per gallon of hot water supplied by electric
               = (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE_electric * 3412)
               = (8.33 * 1.0 * (101 - 54.1)) / (0.98 * 3412)
               = 0.117 kWh/gal

8.33  = Specific weight of water (lbs/gallon)
1.0   = Heat Capacity of water (btu/lb-°)

ShowerTemp = Assumed temperature of water
            = 101°F 656

SupplyTemp = Assumed temperature of water entering house
            = 54.1°F 657

RE_electric = Recovery efficiency of electric water heater
             = 98% 658

3412  = Converts Btu to kWh (btu/kWh)

ISR  = In service rate of showerhead
       = Dependent on program delivery method as listed in table below

<table>
<thead>
<tr>
<th>Selection</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install - Single Family</td>
<td>0.98659</td>
</tr>
<tr>
<td>Direct Install – Multi Family</td>
<td>0.95660</td>
</tr>
<tr>
<td>Efficiency Kits</td>
<td>To be determined through evaluation</td>
</tr>
</tbody>
</table>

654 Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
655 Ibid.
658 Electric water heaters have recovery efficiency of 98%: http://www.ahridirectory.org/ahridirectory/pages/home.aspx
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

$$
\Delta kW = \frac{\Delta kWh}{\text{Hours}} \times CF
$$

Where:

- $\Delta kWh$ = calculated value above
- Hours = Annual electric DHW recovery hours for wasted showerhead use prevented by device
  $$
  = \frac{((\text{GPM}_{\text{base S}} \times \text{L}_{\text{showerdevice}}) \times \text{Household} \times \text{SPCD} \times 365.25) \times 0.712}{\text{GPH}}
  $$
- GPH = Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.
  - 27.51
  - 34.4 for SF Direct Install; 28.3 for MF Direct Install
  - 30.3 for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS
- CF = Coincidence Factor for electric load reduction
  - 0.0022

**EXAMPLE**

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

$$
\Delta kWh = 1.0 \times (2.67 \times 0.89 \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.117 \times 0.98
= 85 \text{ kWh}
$$

**NATURAL GAS SAVINGS**

$$
\Delta \text{Therms} = \%\text{FossilDHW} \times \frac{((\text{GPM}_{\text{base S}} \times \text{L}_{\text{showerdevice}}) \times \text{Household} \times \text{SPCD} \times 365.25)}{\text{SPH}} \times \text{EPG}_{\text{gas}} \times \text{ISR}
$$

Where:

- $\%\text{FossilDHW}$ = proportion of water heating supplied by Natural Gas heating

---

661 71.2% is the proportion of hot 120F water mixed with 54.1F supply water to give 101F shower water.

662 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 29.5 = 0.577 hours of recovery during peak period, where 29.5 equals the average annual electric DHW recovery hours for showerhead use prevented by the device including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 0.577/260 = 0.0022
### Water Impact Descriptions and Calculation

**Example**

For example, a direct installed thermostatic restrictor device in a gas fired DHW single family home where the number of showers is not known:

\[
\Delta \text{Therms} = 1.0 \times (2.67 \times 0.89) \times 2.56 \times 0.6 \times 365.25 / 1.79 \times 0.00501 \times 0.98 = 3.7 \text{ therms}
\]

**Variables as defined above.**

---

663 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.

664 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 78%.

665 Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.
EXAMPLE

For example, a direct installed thermostatic restrictor device in a single family home where the number of showers is not known:

\[ \Delta \text{gallons} = (2.67 \times 0.89) \times 2.56 \times 0.6 \times 365.25 / 1.79 \times 0.98 \]

\[ = 730 \text{ gallons} \]

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

SOURCES

<table>
<thead>
<tr>
<th>Source ID</th>
<th>Reference</th>
</tr>
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<tbody>
<tr>
<td>12</td>
<td>2014, New York State Record of Revision to the TRM, Case 07-M-0548, June 19, 2014.</td>
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</tbody>
</table>

MEASURE CODE: RS-HWE-TRVA-V03-180101

REVIEW DEADLINE: 1/1/2023
5.4.9 Shower Timer

**DESCRIPTION**

Shower Timers are designed to make it easy for people to consistently take short showers, resulting in water and energy savings.

The shower timer provides a reminder to participants on length of their shower visually or auditorily.

This measure was developed to be applicable to the following program type: KITS, DI.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The shower timer should provide a reminder to participants to keep showers to a length of 5 minutes or less.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline is no shower timer.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The deemed lifetime is 2 years.

**DEEMED MEASURE COST**

For shower timers provided in Efficiency Kits, the actual program delivery costs should be utilized.

**LOADSHAPE**

Loadshape R03 - Residential Electric DHW

**COINCIDENCE FACTOR**

The coincidence factor for this measure is assumed to be 2.78%.

---

**Algorithm**

**CALCULATION OF ENERGY SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[ \Delta \text{kWh} = \% \text{Electric DHW} \times \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \times \text{EPG_Electric} \]

Where:

---

666 Estimate of persistence of behavior change instigated by the shower timer.

667 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11*65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96% * 369 = 7.23 hours of recovery during peak period, where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278
%Electric DHW = Proportion of water heating supplied by electric resistance heating

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%ElectricDHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>100%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>16%668</td>
</tr>
</tbody>
</table>

GPM = Flow rate of showerhead as used
= Custom, to be determined through evaluation. If data is not available use 1.93669

L_base = Number of minutes in shower without a shower timer
= 7.8 minutes670

L_timer = Number of minutes in shower after shower timer
= Custom, to be determined through evaluation. If data is not available use 5.79671

Household = Number in household using timer

<table>
<thead>
<tr>
<th>Household Unit Type672</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56673</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1674</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms675</td>
</tr>
</tbody>
</table>

Days/yr = 365.25

SPCD = Showers Per Capita Per Day
= 0.6676

UsageFactor = How often each participant is using shower timer
= Custom, to be determined through evaluation. If data is not available use 0.34677

EPG_Electric = Energy per gallon of hot water supplied by electric

---

668 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.


670 Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group. This study of 135 single and multi-family homes in Michigan metered energy parameters for efficient showerhead and faucet aerators.


672 If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.


674 ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx

675 Bedrooms are suitable proxies for household occupancy, and may be preferable to actual occupancy due to turnover rates in residency and non-adult population impacts.


\[
= \frac{(8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp}))}{(\text{RE}_{\text{electric}} \times 3412)}
\]
\[
= \frac{(8.33 \times 1.0 \times (101 - 54.1))}{(0.98 \times 3412)}
\]
\[= 0.117 \text{ kWh/gal}\]

Based on default assumptions provided above, the savings for a single family home would be:

\[\Delta \text{kWh} = \%\text{Electric DHW} \times \text{GPM} \times (\text{L}_{\text{base}} - \text{L}_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \times \text{EPG}_{\text{Electric}}\]
\[= 0.16 \times 1.93 \times (7.8 - 5.79) \times 2.56 \times 365.25 \times 0.6 \times 0.34 \times 0.117\]
\[= 13.9 \text{kWh}\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[\Delta \text{kW} = \Delta \text{kWh}/\text{Hours} \times \text{CF}\]

Where:
- \(\Delta \text{kWh}\) = calculated value above
- \text{Hours} = Annual electric DHW recovery hours for showerhead use
- \text{CF} = Coincidence Factor for electric load reduction
  \[= 0.0278^678\]

Based on default assumptions provided above, the savings for a single family home would be:

\[\Delta \text{kW} = \Delta \text{kWh}/\text{Hours} \times \text{CF}\]
\[= 0.0013 \text{ kW}\]

**NATURAL GAS SAVINGS**

\[\Delta \text{Therms} = \%\text{FossilDHW} \times \text{GPM} \times (\text{L}_{\text{base}} - \text{L}_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \times \text{EPG}_{\text{Gas}}\]
\[\%\text{FossilDHW} = \text{Proportion of water heating supplied by electric resistance heating}\]

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%FossilDHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>0%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>100%</td>
</tr>
<tr>
<td>Unknown</td>
<td>84%</td>
</tr>
</tbody>
</table>

^678 Calculated as follows: Assume 11% showers take place during peak hours (based on: Oreo et al., “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11\times 65/365 = 1.96%. The number of hours of recovery during peak periods is therefore assumed to be 1.96\% \times 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278

^679 Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used.
EPG\_gas = Energy per gallon of Hot water supplied by gas
= (8.33 * 1.0 * (ShowerTemp - SupplyTemp)) / (RE\_gas * 100,000)
= 0.00501 Therm/gal for SF homes
= 0.00583 Therm/gal for MF homes

RE\_gas = Recovery efficiency of gas water heater
= 78% For SF homes
= 67% For MF homes

100,000 = Converts Btus to Therms (btu/Therm)

Other variables as defined above.

Based on default assumptions provided above, the savings for a single family home would be:

\[ \Delta \text{Therms} = \%\text{FossilDHW} \times \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \times \text{EPG\_Gas} \]

\[ = 0.84 \times 1.93 \times (7.8 - 5.79) \times 2.56 \times 365.25 \times 0.6 \times 0.34 \times 0.00501 \]

\[ = 3.1 \text{ Therms} \]

**WATER DESCRIPTIONS AND CALCULATION**

\[ \Delta \text{Gallons} = \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \]

Variables as defined above

Based on default assumptions provided above, the savings for a single family home would be:

\[ \Delta \text{Gallons} = 1.93 \times (7.8 - 5.79) \times 2.56 \times 365.25 \times 0.6 \times 0.34 \]

\[ = 740.0 \text{ gallons} \]

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-DHW-SHTM-V01-180101

**REVIEW DEADLINE:** 1/1/2019

---

680 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 78%.

681 Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings.
5.5 Lighting End Use
5.5.1 Compact Fluorescent Lamp (CFL)

DESCRIPTION

A low wattage qualified compact fluorescent screw-in bulb (CFL) is installed in place of a baseline screw-in bulb. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program), a deemed split of 95% Residential and 5% Commercial assumptions should be used.682

Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) required all general-purpose light bulbs between 40W and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ended in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a standard qualified compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline equipment is assumed to be an EISA qualified incandescent or halogen as provided in the table provided in the Electric Energy Savings section.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life (number of years that savings should be claimed) for bulbs installed in 2018 is assumed to be 3 years and then for every subsequent year should be reduced by one year.683

682 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See ‘RESvCI Split_112016.xls’.
683 Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.
DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost is $1.20\(^{684}\).

For the Direct Install measure, the full cost of $2.45 per bulb should be used, plus $5 labor cost\(^{685}\) for a total of $7.45 per bulb. However actual program delivery costs should be utilized if available.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be utilized.

LOADSHAPE

- Loadshape R06 - Residential Indoor Lighting
- Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1% for Time of Sale Residential and in-unit Multi Family bulbs, 27.3% for exterior bulbs and 8.1% for unknown\(^{686}\) and 7.4% for Residential Direct Install\(^{687}\).

Calculation of Savings

\[ \Delta \text{kWh} = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times (1 - \text{Leakage}) \times \text{Hours} \times \text{WHFe} \]

Where:

- \( \text{WattsBase} \) = Based on lumens of CFL bulb and program year installed:

<table>
<thead>
<tr>
<th>Minimum Lumens</th>
<th>Maximum Lumens</th>
<th>Incandescent Equivalent Post-EISA 2007 (WattsBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5280</td>
<td>6209</td>
<td>300</td>
</tr>
<tr>
<td>3000</td>
<td>5279</td>
<td>200</td>
</tr>
<tr>
<td>2601</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td>1490</td>
<td>2600</td>
<td>72</td>
</tr>
<tr>
<td>1050</td>
<td>1489</td>
<td>53</td>
</tr>
<tr>
<td>750</td>
<td>1049</td>
<td>43</td>
</tr>
<tr>
<td>310</td>
<td>749</td>
<td>29</td>
</tr>
<tr>
<td>250</td>
<td>309</td>
<td>25</td>
</tr>
</tbody>
</table>

- \( \text{WattsEE} \) = Actual wattage of CFL purchased / installed

\(^{684}\) Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

\(^{685}\) Based on 15 minutes at $20 an hour. Includes some portion of travel time to site.

\(^{686}\) Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\(^{687}\) Based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation and excluding all logged bulbs installed in closets.
ISR = In Service Rate, the percentage of units rebated that are actually in service.

<table>
<thead>
<tr>
<th>Program</th>
<th>Weighted Average 1st Year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale)</td>
<td>76.5%(^{688})</td>
<td>11.6%</td>
<td>9.9%</td>
<td>98.0%(^{689})</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9%(^{690})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency Kits(^{691})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFL Distribution(^{692})</td>
<td>59%</td>
<td>13%</td>
<td>11%</td>
<td>83%</td>
</tr>
<tr>
<td>School Kits(^{693})</td>
<td>61%</td>
<td>13%</td>
<td>11%</td>
<td>86%</td>
</tr>
<tr>
<td>Direct Mail Kits(^{694})</td>
<td>66%</td>
<td>14%</td>
<td>12%</td>
<td>93%</td>
</tr>
</tbody>
</table>

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate\(^{695}\)) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below\(^{696}\):

- ComEd: 2.1%
- Ameren: 13.1%
- All other programs = 0

\(^{688}\) 1st year in service rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see ‘IL RES Lighting ISR_112016.xls’ for more information). The average first year ISR for each utility was calculated weighted by the number of bulbs in the each year’s survey. This was then weighted by annual sales to give a statewide assumption.

\(^{689}\) The 98% Lifetime ISR assumption is based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; ‘New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report; Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

\(^{690}\) Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

\(^{691}\) In Service Rates provided are for the CFL bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provided may be used.

\(^{692}\) Free bulbs provided without request, with little or no education. Based on ‘Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program’, Report Table 11 and Appendix B.

\(^{693}\) Kits provided free to students through school, with education program. Based on ‘Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program’, table 10. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs.

\(^{694}\) Opt-in program to receive kits via mail, with little or no education. Based on ‘Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential Efficiency Kits Program’, table 10, as above.

\(^{695}\) Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

\(^{696}\) Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see ‘IL Leakage Rates_112016.xls’ for more information).
**Compact Fluorescent Lamp (CFL)**

| Program Delivery | Installation Location | Hours
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale) and Efficiency Kits</td>
<td>Residential Interior and in-unit Multi Family</td>
<td>759</td>
</tr>
<tr>
<td></td>
<td>Exterior</td>
<td>2,475</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>847</td>
</tr>
<tr>
<td>Direct Install</td>
<td>Residential Interior and in-unit Multi Family</td>
<td>793</td>
</tr>
<tr>
<td></td>
<td>Exterior</td>
<td>2,475</td>
</tr>
</tbody>
</table>

\[
\text{WHFe} = \text{Waste heat factor for energy to account for cooling energy savings from efficient lighting}\]

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.06</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.04</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Deferred Installs**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- **Year 1 (Purchase Year) installs:** Characterized using assumptions provided above or evaluated assumptions if available.
- **Year 2 and 3 installs:** Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

---

697 Except where noted, based on lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation. Direct Install value excludes all logged bulbs installed in closets.

698 Based on secondary research conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation.

699 Assumes 5% exterior lighting, based on PYPY5/PY6 ComEd Residential Lighting Program evaluation.

700 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling (“Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration”, 2009 Residential Energy Consumption Survey)

701 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)
HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[ \Delta k\text{WH} = -[((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times \text{Hours} \times \text{HF}) / \eta\text{Heat}] \]

Where:

- HF = Heating Factor or percentage of light savings that must be heated
  = 49% for interior or unknown location
  = 0% for exterior or unheated location
- \( \eta\text{Heat} \) = Efficiency in COP of Heating equipment
  = actual. If not available use:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP\text{HEAT} (COP Estimate) = (HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown\text{\textsuperscript{705}}</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

\textsuperscript{702} Negative value because this is an increase in heating consumption due to the efficient lighting.

\textsuperscript{703} This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

\textsuperscript{704} 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. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

\textsuperscript{705} Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.
For example, a 14W standard CFL is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

\[
\Delta k\text{Wh}_{1\text{st year}} = -(((43 - 14) / 1000) * 0.765 * 759 * 0.49) / 2.0
\]

= - 4.2 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

\[
\text{WHFd} = \text{Waste heat factor for demand to account for cooling savings from efficient lighting.}
\]

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.11</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[
\text{CF} = \text{Summer Peak Coincidence Factor for measure.}
\]

<table>
<thead>
<tr>
<th>Program Delivery</th>
<th>Bulb Location</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail(Time of Sale)</td>
<td>Interior single family or Multi Family in unit</td>
<td>7.1%</td>
</tr>
<tr>
<td></td>
<td>Exterior</td>
<td>27.3%</td>
</tr>
<tr>
<td></td>
<td>Unknown location</td>
<td>8.1%</td>
</tr>
<tr>
<td>Direct Install</td>
<td>Residential</td>
<td>7.4%</td>
</tr>
</tbody>
</table>

Other factors as defined above

For example, a 14W standard CFL is purchased and installed in a single family interior location:

\[
\Delta kW = ((43 - 14) / 1000) * 0.765 * 1.11 * 0.071
\]

= 0.0017 kW

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

---

706 The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

707 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

708 Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation. Direct Install value is based on resut excluding all logged bulbs installed in closets.
NATURAL GAS SAVINGS

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

\[
\Delta \text{Therms} = - \left( \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412 \right) / \eta_{\text{Heat}}
\]

Where:

- HF = Heating Factor or percentage of light savings that must be heated
  - 49%\(^\text{710}\) for interior or unknown location
  - 0% for exterior or unheated location
- 0.03412 = Converts kWh to Therms
- \(\eta_{\text{Heat}}\) = Efficiency of heating system
  - 70%\(^\text{711}\)

For example, a 14 standard CFL is purchased and installed in a home:

\[
\Delta \text{Therms} = - \left( \frac{(43 - 14)}{1000} \times 0.765 \times 759 \times 0.49 \times 0.03412 \right) / 0.7
\]

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

---

\(^{709}\) Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{710}\) This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

\(^{711}\) This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey) In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70\]
<table>
<thead>
<tr>
<th>Program Delivery</th>
<th>Installation Location</th>
<th>Replacement Period (years)(^\text{712})</th>
<th>Replacement Cost(^\text{713})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale) and Efficiency Kits</td>
<td>Residential Interior and in-unit Multi Family</td>
<td>1.3</td>
<td>$1.25</td>
</tr>
<tr>
<td></td>
<td>Exterior</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Direct Install</td>
<td>Residential Interior and in-unit Multi Family</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exterior</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs are actually in service and so should be multiplied by the appropriate ISR.

**Measure Code:** RS-LTG-ESCF-V06-180101

**Review Deadline:** 1/1/2020

---

\(^{712}\) Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

\(^{713}\) Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
5.5.2 ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

DESCRIPTION

A qualified specialty compact fluorescent bulb is installed in place of an incandescent specialty bulb.

Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 ([https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf](https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf)). The efficacy requirements cannot currently be met by Compact Fluorescent Lamps, and therefore this specification has been removed. ENERGY STAR will maintain a list on their website with the final qualifying list of products prior to this change and it is strongly recommended that programs continue to use this list as qualifying criteria for products in the programs.

This characterization assumes that the specialty CFL is installed in a residential location. If the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used\(^\text{714}\).

This measure was developed to be applicable to the following program types: TOS, NC, DI, KITS.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

In order for this characterization to apply, the high-efficiency equipment must be a qualified specialty compact fluorescent lamp.

DEFINITION OF BASELINE EQUIPMENT

The baseline is a specialty incandescent light bulb including those exempt of the EISA 2007 standard: three-way, plant light, daylight bulb, bug light, post light, globes G40 (<40W), candelabra base (<60W), vibration service bulb, decorative candle with medium or intermediate base (<40W), shatter resistant and reflector bulbs and standard bulbs greater than 2601 lumens, and those non-exempt from EISA 2007: dimmable, globes (less than 5” diameter and >40W), candle (shapes B, BA, CA >40W, candelabra base lamps >60W) and intermediate base lamps (>40W).

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 6.8 year\(^\text{715}\) for bulbs exempt from EISA, or 3 years for bulbs non-exempt installed in 2018 and then for every subsequent year should be reduced by one year\(^\text{716}\).

DEEMED MEASURE COST

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5\(^\text{717}\).

For the Direct Install measure, the full cost of $8.50 should be used plus $5 labor\(^\text{718}\) for a total of $13.50. However

\(^{714}\) RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See "RESvCI Split_112015.xls".

\(^{715}\) The assumed measure life for the specialty bulb measure characterization was reported in "Residential Lighting Measure Life Study", Nexus Market Research, June 4, 2008 (measure life for markdown bulbs). Measure life estimate does not distinguish between equipment life and measure persistence. Measure life includes products that were installed and operated until failure (i.e., equipment life) as well as those that were retired early and permanently removed from service for any reason, be it early failure, breakage, or the respondent not liking the product (i.e., measure persistence).

\(^{716}\) Since the replacement baseline bulb from 2020 on will be equivalent to a CFL, no additional savings should be claimed from that point. Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

\(^{717}\) NEEP Residential Lighting Survey, 2011

\(^{718}\) Based on 15 minutes at $20 per hour.
actual program delivery costs should be utilized if available.

For bulbs provided in Efficiency Kits, the actual program delivery costs should be utilized.

**LOADSHAPE**

- Loadshape R06 - Residential Indoor Lighting
- Loadshape R07 - Residential Outdoor Lighting

**COINCIDENCE FACTOR**

Unlike standard CFLs that could be installed in any room, certain types of specialty CFLs are more likely to be found in specific rooms, which affects the coincident peak factor. Coincidence factors by bulb types are presented below.\(^{719}\)

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Peak CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>0.078(^{720})</td>
</tr>
<tr>
<td>Dimmable</td>
<td>0.078(^{721})</td>
</tr>
<tr>
<td>Interior reflector (incl. dimmable)</td>
<td>0.091</td>
</tr>
<tr>
<td>Exterior reflector</td>
<td>0.273</td>
</tr>
<tr>
<td>Candelabra base and candle medium and intermediate base</td>
<td>0.121</td>
</tr>
<tr>
<td>Bug light</td>
<td>0.273</td>
</tr>
<tr>
<td>Post light (&gt;100W)</td>
<td>0.273</td>
</tr>
<tr>
<td>Daylight</td>
<td>0.081</td>
</tr>
<tr>
<td>Plant light</td>
<td>0.081</td>
</tr>
<tr>
<td>Globe</td>
<td>0.075</td>
</tr>
<tr>
<td>Vibration or shatterproof</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, Residential, Multi-family in unit</td>
<td>0.071</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, unknown</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, exterior</td>
<td>0.273</td>
</tr>
<tr>
<td>Specialty - Generic</td>
<td>0.081</td>
</tr>
</tbody>
</table>

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta\text{kWh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times (1 - \text{Leakage}) \times \text{Hours} \times \text{WHFe}
\]

Where:

- \text{WattsBase} = \text{Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain the incandescent bulb equivalent wattage}\(^{722}\); use 60W if unknown.\(^{723}\)

---

\(^{719}\) Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\(^{720}\) Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\(^{721}\) Ibid


EISA exempt bulb types:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Spirals &gt;=2601</td>
<td>2601</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>5279</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>5280</td>
<td>6209</td>
<td>300</td>
</tr>
<tr>
<td>3-Way</td>
<td>250</td>
<td>449</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>799</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>1099</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>1100</td>
<td>1599</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>1999</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>2000</td>
<td>2549</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>2550</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td>Globe (medium and intermediate bases less than 750 lumens)</td>
<td>90</td>
<td>179</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>349</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>749</td>
<td>40</td>
</tr>
<tr>
<td>Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)</td>
<td>70</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>149</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>299</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>749</td>
<td>40</td>
</tr>
<tr>
<td>Globe (candelabra bases less than 1050 lumens)</td>
<td>90</td>
<td>179</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>349</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>499</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>1049</td>
<td>60</td>
</tr>
<tr>
<td>Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)</td>
<td>70</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>149</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>299</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>499</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>1049</td>
<td>60</td>
</tr>
</tbody>
</table>

**Directional Lamps** - ENERGY STAR Minimum Luminous Efficacy = 40Lm/W for lamps with rated wattages less than 20W and 50 Lm/W for lamps with rated wattages >= 20 watts\(^2\)\(^4\).

For Directional R, BR, and ER lamp types\(^2\)\(^5\):

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>420</td>
<td>472</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>473</td>
<td>524</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>525</td>
<td>714</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>715</td>
<td>937</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>938</td>
<td>1259</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>1260</td>
<td>1399</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>1400</td>
<td>1739</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>1740</td>
<td>2174</td>
<td>120</td>
</tr>
</tbody>
</table>

\(^2\)\(^4\) From pg 10 of the Energy Star Specification for lamps v1.1
\(^2\)\(^5\) From pg 11 of the Energy Star Specification for lamps v1.1
### Bulb Type

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>R, BR, and ER with medium screw bases w/ diameter &lt;= 2.25&quot;</td>
<td>2175</td>
<td>2624</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>2625</td>
<td>2999</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>3000</td>
<td>4500</td>
<td>200</td>
</tr>
<tr>
<td>*R, BR, and ER with medium screw bases w/ diameter &lt;= 2.25&quot;</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>499</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>649</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>1199</td>
<td>65</td>
</tr>
<tr>
<td>*ER30, BR30, BR40, or ER40</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>499</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>649</td>
<td>50</td>
</tr>
<tr>
<td>*BR30, BR40, or ER40</td>
<td>650</td>
<td>1419</td>
<td>65</td>
</tr>
<tr>
<td>*R20</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td>*All reflector lamps below lumen ranges specified above</td>
<td>450</td>
<td>719</td>
<td>45</td>
</tr>
</tbody>
</table>

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool.²²⁶ 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.²²⁷

\[
\text{WattsBase} = \frac{375.1 - 4.355(D) - \sqrt{227,800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D * BA) + 14.69(BA^2) - 16,720 \ln(CBCP)}}{800 - 937.9(D)}
\]

Where:

- \(D\) = Bulb diameter (e.g. for PAR20 \(D = 20\))
- \(BA\) = Beam angle
- \(CBCP\) = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Permitted Wattages</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>20, 35, 40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>30S</td>
<td>40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>30L</td>
<td>50, 75</td>
</tr>
<tr>
<td>38</td>
<td>40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250</td>
</tr>
</tbody>
</table>

EISA non-exempt bulb types:


²²⁷ The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.
### Bulb Type

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Incandescent Equivalent Post-EISA 2007 (WattsBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimmable Twist, Globe (less than 5&quot; in diameter and &gt; 749 lumens),</td>
<td>310</td>
<td>749</td>
<td>29</td>
</tr>
<tr>
<td>candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt;1049</td>
<td>750</td>
<td>1049</td>
<td>43</td>
</tr>
<tr>
<td>lumens), Intermediate Base Lamps (&gt;749 lumens)</td>
<td>1050</td>
<td>1489</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>1490</td>
<td>2600</td>
<td>72</td>
</tr>
</tbody>
</table>

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

**ISR** = In Service Rate, the percentage of units rebated that are actually in service.

<table>
<thead>
<tr>
<th>Program</th>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale)</td>
<td>88.0%&lt;sup&gt;729&lt;/sup&gt;</td>
<td>5.4%</td>
<td>4.6%</td>
<td>98.0%&lt;sup&gt;730&lt;/sup&gt;</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9%&lt;sup&gt;731&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency Kits&lt;sup&gt;732&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFL Distribution</td>
<td>59%</td>
<td>13%</td>
<td>11%</td>
<td>83%</td>
</tr>
<tr>
<td>School Kits&lt;sup&gt;734&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct Mail Kits&lt;sup&gt;735&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>14%</td>
<td>12%</td>
<td>93%</td>
</tr>
</tbody>
</table>

**Leakage** = Adjustment to account for the percentage of program bulbs that move out (and in if...


<sup>729</sup> 1<sup>st</sup> year in service rate is based upon review of PY4-6 evaluations from ComEd and PY5-6 from Ameren (see ‘IL RES Lighting ISR_122014.xls’ for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year’s survey.

<sup>730</sup> The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:

‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2<sup>nd</sup> and 3<sup>rd</sup> year installations should be counted as part of those future program year savings.

<sup>731</sup> Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type). Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

<sup>732</sup> In Service Rates provided are for the bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provide may be used.

<sup>733</sup> Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

<sup>734</sup> Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

<sup>735</sup> Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.
Illinois Statewide Technical Reference Manual – 5.5.2 ENERGY STAR Specialty Compact Fluorescent Lamp (CFL)

deemed appropriate\(^{736}\) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below\(^{737}\):

- ComEd: 2.1%
- Ameren: 13.1%
- All other programs = 0

Hours = Average hours of use per year, varies by bulb type as presented below\(^{738}\)

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Annual hours of use (HOU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>850</td>
</tr>
<tr>
<td>Dimmable</td>
<td>850</td>
</tr>
<tr>
<td>Interior reflector (incl. dimmable)</td>
<td>861</td>
</tr>
<tr>
<td>Exterior reflector</td>
<td>2475</td>
</tr>
<tr>
<td>Candelabra base and candle medium and intermediate base</td>
<td>1190</td>
</tr>
<tr>
<td>Bug light</td>
<td>2475</td>
</tr>
<tr>
<td>Post light (&gt;100W)</td>
<td>2475</td>
</tr>
<tr>
<td>Daylight</td>
<td>847</td>
</tr>
<tr>
<td>Plant light</td>
<td>847</td>
</tr>
<tr>
<td>Globe</td>
<td>639</td>
</tr>
<tr>
<td>Vibration or shatterproof</td>
<td>847</td>
</tr>
<tr>
<td>Standard Spiral &gt;2601 lumens, Residential, Multi Family in-unit</td>
<td>759</td>
</tr>
<tr>
<td>Standard Spiral &gt;2601 lumens, unknown</td>
<td>847</td>
</tr>
<tr>
<td>Standard Spiral &gt;2601 lumens, Exterior</td>
<td>2475</td>
</tr>
<tr>
<td>Specialty - Generic</td>
<td>847</td>
</tr>
</tbody>
</table>

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.06 (^{739})</td>
</tr>
</tbody>
</table>

\(^{736}\) Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

\(^{737}\) Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see ‘IL Leakage Rates_112016.xls’ for more information).

\(^{738}\) Hours of use by specialty bulb type calculated using the average hours of use in locations or rooms where each type of specialty bulb is most commonly found. Values for Reflector, Decorative and Globe are taken directly from the lighting logger study conducted as part of the PY5/PY6 ComEd Residential Lighting Program evaluation. All other hours have been updated based on the room specific hours of use from the PY5/PY6 logger study.

\(^{739}\) The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8))). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling (“Table HC7.9  Air Conditioning in Homes in Midwest...”)
### Deferred Installs

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- Year 1 (Purchase Year) installs: Characterized using assumptions provided above or evaluated assumptions if available.
- Year 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

---

#### Example Calculation

For example, for a 13W dimmable CFL impacted by EISA 2007 (60W standard incandescent and 43W EISA qualified incandescent/halogen):

\[
\Delta kWH_{1st\ year\ installs} = \frac{(60 - 13)}{1000} \times 0.823 \times 850 \times 1.06 = 34.9 \text{ kWh}
\]

\[
\Delta kWH_{2nd\ year\ installs} = \frac{(43 - 13)}{1000} \times 0.085 \times 850 \times 1.06 = 2.3 \text{ kWh}
\]

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

\[
\Delta kWH_{3rd\ year\ installs} = \frac{(43 - 13)}{1000} \times 0.072 \times 850 \times 1.06 = 1.9 \text{ kWh}
\]

Note: delta watts is equivalent to install year. Here we assume no change in hours assumption.

---

#### Heating Penalty

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[
\Delta kW_h = - \left(\frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{Hours} \times \text{HF}\right) / \eta_{\text{Heat}}
\]

Where:

- \(\text{HF}\) = Heating Factor or percentage of light savings that must be heated

  - 49%\(^{742}\) for interior or unknown location
  - 0% for exterior location

- \(\eta_{\text{Heat}}\) = Efficiency in COP of Heating equipment

---

\(^{740}\) As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

\(^{741}\) Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{742}\) This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.
= actual. If not available use[^743]:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>HSPF (COP Estimate) = (HSPF/3.413) * 0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown[^744]</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

For example, a 15W globe CFL replacing a 60W incandescent specialty bulb installed in home with 2.0 COP Heat Pump (including duct loss):

\[ \Delta kW_{1\text{st\ year}} = - \frac{(60 - 15)}{1000} \times 0.823 \times 639 \times 0.49}{2.0} \]
\[ = - 5.8 \text{ kWh} \]

Second and third year savings should be calculated using the appropriate ISR.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{WHFd} \times \text{CF} \]

Where:

\[ \text{WHFd} = \text{Waste heat factor for demand to account for cooling savings from efficient lighting.} \]

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.11[^745]</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07[^746]</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[ \text{CF} = \text{Summer Peak Coincidence Factor for measure. Coincidence factors by bulb types are presented below[^747]} \]

[^743]: 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. Note efficiency should include duct losses. Defauts provided assume 15% duct loss for heat pumps.

[^744]: Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

[^745]: The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

[^746]: As above but using estimate of 45% of multifamily buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average); [http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls](http://205.254.135.7/consumption/residential/data/2009/xls/HC7.1%20Air%20Conditioning%20by%20Housing%20Unit%20Type.xls).

[^747]: Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.
### Bulb Type

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Peak CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>0.078748</td>
</tr>
<tr>
<td>Dimmable</td>
<td>0.078749</td>
</tr>
<tr>
<td>Interior reflector (incl. dimmable)</td>
<td>0.091</td>
</tr>
<tr>
<td>Exterior reflector</td>
<td>0.273</td>
</tr>
<tr>
<td>Candelabra base and candle medium and intermediate base</td>
<td>0.121</td>
</tr>
<tr>
<td>Bug light</td>
<td>0.273</td>
</tr>
<tr>
<td>Post light (&gt;100W)</td>
<td>0.273</td>
</tr>
<tr>
<td>Daylight</td>
<td>0.081</td>
</tr>
<tr>
<td>Plant light</td>
<td>0.081</td>
</tr>
<tr>
<td>Globe</td>
<td>0.075</td>
</tr>
<tr>
<td>Vibration or shatterproof</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard Spiral &gt;=2601 lumens, Residential, Multi-family in unit</td>
<td>0.071</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, unknown</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, exterior</td>
<td>0.273</td>
</tr>
<tr>
<td>Specialty - Generic</td>
<td>0.081</td>
</tr>
</tbody>
</table>

**Other factors as defined above**

For example, a 15W specialty CFL replacing a 60W incandescent specialty bulb:

\[
\Delta kW_{1st\ year} = \frac{(60 - 15)}{1000} \times 0.823 \times 1.11 \times 0.081 = 0.003\ kW
\]

Second and third year savings should be calculated using the appropriate ISR.

### Natural Gas Savings

**Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):**

\[
\Delta\text{Therms}^{750} = -((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412 / \eta\text{Heat}
\]

Where:

- \(\text{HF}\) = Heating Factor or percentage of light savings that must be heated
  - \(49\%\)\(^{751}\) for interior or unknown location
  - \(0\%\) for exterior location
- 0.03412 = Converts kWh to Therms
- \(\eta\text{Heat}\) = Efficiency of heating system
  - \(70\%\)\(^{752}\)

\(^{748}\) Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\(^{749}\) Ibid

\(^{750}\) Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{751}\) This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

\(^{752}\) This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular
For example, a 15W Globe specialty CFL replacing a 60W incandescent specialty bulb:

\[
\Delta \text{Therms} = \frac{((60 - 15) \times 0.823 \times 639 \times 0.49 \times 0.03412)}{0.7} = 0.57 \text{ Therms}
\]

Second and third year savings should be calculated using the appropriate ISR.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The following O&M assumptions should be used: Life of the baseline bulb is assumed to be 1.32 year\(^{753}\); baseline replacement cost is assumed to be $3.5\(^{754}\).

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE:** RS-LTG-ESCC-V05-180101

**REVIEW DEADLINE:** 1/1/2020

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\(^{753}\) Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32

\(^{754}\) NEEP Residential Lighting Survey, 2011
5.5.3 ENERGY STAR Torchiere

DESCRIPTION

A high efficiency ENERGY STAR fluorescent torchiere is purchased in place of a baseline mix of halogen and incandescent torchieres and installed in a residential setting.

This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

To qualify for this measure the fluorescent torchiere must meet ENERGY STAR efficiency standards.

DEFINITION OF BASELINE EQUIPMENT

The baseline is based on a mix of halogen and incandescent torchieres.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The lifetime of the measure is assumed to be 8 years\textsuperscript{755}.

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $5\textsuperscript{756}.

LOADSHAPE

Loadshape R06 - Residential Indoor Lighting
Loadshape R07 - Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is 7.1% for Residential and in-unit Multi Family bulbs and 8.1% for bulbs installed in unknown locations\textsuperscript{757}.

Algorithm

CALCULATION OF SAVINGS

\textbf{ELECTRIC ENERGY SAVINGS}

\[
\Delta \text{kWh} = (\Delta \text{Watts} /1000) \times \text{ISR} \times (1-\text{Leakage}) \times \text{HOURS} \times \text{WHFe}
\]

Where:

\[
\Delta \text{Watts} = \text{Average delta watts per purchased ENERGY STAR torchiere} = 115.8 \text{\textsuperscript{758}}
\]


\textsuperscript{756} DEER 2008 Database Technology and Measure Cost Data (\texttt{www.deeresources.com}) and consistent with Efficiency Vermont TRM.

\textsuperscript{757} Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{758} Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting
ISR = In Service Rate or percentage of units rebated that get installed.

= 0.86

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below:

ComEd: 2.1%
Ameren: 13.1%
All other programs = 0

HOURS = Average hours of use per year

<table>
<thead>
<tr>
<th>Installation Location</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential and in-unit Multi Family</td>
<td>1095 (3.0 hrs per day)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.06</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.04</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

For single family buildings:

\[ \Delta\text{kWh} = \frac{(115.8/1000) \times 0.86 \times 1095 \times 1.06}{1000} = 116 \text{kWh} \]

Programs, Final Report, October 1, 2004, p. 43 (Table 4-9)

Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see ‘IL Leakage Rates_112016.xls’ for more information).

The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8))). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm \(-0.02 \times \text{SEER}^2 + (1.12 \times \text{SEER})\) from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling (“Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration”, 2009 Residential Energy Consumption Survey)

As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)
For multi family in unit:

$$\Delta kWh = \frac{(115.8 / 1000) \times 0.86 \times 1095 \times 1.04}{1} = 113 \text{ kWh}$$

**Heating Penalty**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

$$\Delta kWh = - \frac{((\Delta Watts) / 1000) \times ISR \times HOURS \times HF)}{\eta_{Heat}}$$

Where:

- HF = Heating Factor or percentage of light savings that must be heated
  
- $49\%^{766}$ for interior or unknown location

- $\eta_{Heat}$ = Efficiency in COP of Heating equipment
  
- = Actual. If not available use defaults provided below$^{767}$:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP Heat (COP Estimate) = (HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown$^{768}$</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

For example, an ES torchiere installed in a house with a 2016 heat pump:

$$\Delta kWh = - \frac{(115.8) / 1000) \times 0.86 \times 1095 \times 0.49}{2.04} = - 26.2 \text{ kWh}$$

**Summer Coincident Peak Demand Savings**

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

Where:

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

---

$^{765}$ Negative value because this is an increase in heating consumption due to the efficient lighting.

$^{766}$ This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

$^{767}$ 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. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

$^{768}$ Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.
<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.11\textsuperscript{769}</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07\textsuperscript{770}</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[ CF = \text{Summer Peak Coincidence Factor for measure} \]

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>CF\textsuperscript{771}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or Multi family in unit</td>
<td>7.1%</td>
</tr>
<tr>
<td>Unknown location</td>
<td>8.1%</td>
</tr>
</tbody>
</table>

For single family and multi-family in unit buildings:

\[
\Delta kW = \frac{(115.8 / 1000) \times 0.86 \times 1.11 \times 0.071}{\eta_{Heat}}
\]

\[
= 0.008 \text{kW}
\]

For unknown location:

\[
\Delta kW = \frac{(115.8 / 1000) \times 0.86 \times 1.07 \times 0.081}{\eta_{Heat}}
\]

\[
= 0.009 \text{kW}
\]

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

\[
\Delta \text{Therms}_{WH} = - \left( \frac{\Delta \text{Watts}}{1000} \times \text{ISR} \times \text{HOURS} \times 0.03412 \times \text{HF} \right) / \eta_{Heat}
\]

Where:

\[
\Delta \text{Therms}_{WH} = \text{gross customer annual heating fuel increased usage for the measure from the reduction in lighting heat in therms.}
\]

\[
0.03412 = \text{conversion from kWh to therms}
\]

\[
\text{HF} = \text{Heating Factor or percentage of light savings that must be heated}
\]

\[
= 49\% \text{\textsuperscript{772}}
\]

\[
\eta_{Heat} = \text{average heating system efficiency}
\]

\[
= 70\% \text{\textsuperscript{773}}
\]

\textsuperscript{769} The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

\textsuperscript{770} As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

\textsuperscript{771} Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{772} This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

\textsuperscript{773} This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:
\[ \Delta \text{Therms}_{\text{WH}} = - \left( \frac{115.8}{1000} \times 0.86 \times 1095 \times 0.03412 \times 0.49 \right) / 0.70 \]
\[ = - 2.60 \text{ therms} \]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Life of the baseline bulb is assumed to be 1.83 years\(^{774}\) for residential and multifamily in unit. Baseline bulb cost replacement is assumed to be $6.\(^{775}\)

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-ESTO-V04-180101**

**REVIEW DEADLINE: 1/1/2020**

\[ (0.24 \times 0.92) + (0.76 \times 0.8) \times (1 - 0.15) = 0.70 \]
\(^{774}\) Based on VEIC assumption of baseline bulb (mix of incandescent and halogen) average rated life of 2000 hours, 2000/1095 = 1.83 years.

\(^{775}\) Derived from Efficiency Vermont TRM.
5.5.4 Exterior Hardwired Compact Fluorescent Lamp (CFL) Fixture

**DESCRIPTION**

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an exterior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

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

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standard EISA qualified incandescent or halogen exterior fixture as provided in the table provided in the Electric Energy Savings section.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected life of an exterior fixture is 20 years\(^{776}\). However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years\(^{777}\).

**DEEMED MEASURE COST**

The incremental cost for an exterior fixture is assumed to be $32\(^{778}\).

**LOADSHAPE**

Loadshape R07 - Residential Outdoor Lighting

---


\(^{777}\) Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 27.3%.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta kWh = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times (1 - \text{Leakage}) \times \text{Hours}$$

Where:

- **WattsBase** = Based on lumens of CFL bulb and program year purchased:

<table>
<thead>
<tr>
<th>Minimum Lumens</th>
<th>Maximum Lumens</th>
<th>Incandescent Equivalent Post-EISA 2007 (WattsBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5280</td>
<td>6209</td>
<td>300</td>
</tr>
<tr>
<td>3000</td>
<td>5279</td>
<td>200</td>
</tr>
<tr>
<td>2601</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td>1490</td>
<td>2600</td>
<td>72</td>
</tr>
<tr>
<td>1050</td>
<td>1489</td>
<td>53</td>
</tr>
<tr>
<td>750</td>
<td>1049</td>
<td>43</td>
</tr>
<tr>
<td>310</td>
<td>749</td>
<td>29</td>
</tr>
<tr>
<td>250</td>
<td>309</td>
<td>25</td>
</tr>
</tbody>
</table>

- **WattsEE** = Actual wattage of CFL purchased
- **ISR** = In Service Rate or the percentage of units rebated that get installed.

<table>
<thead>
<tr>
<th>Program</th>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale)</td>
<td>87.5%(^{780})</td>
<td>5.7%</td>
<td>4.8%</td>
<td>98.0%(^{781})</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9(^{782})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Leakage** = Adjustment to account for the percentage of program bulbs that move out (and in if

\(^{779}\) Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\(^{780}\) 1\(^{st}\) year in service rate is based upon review of PY2-3 evaluations from ComEd (see ‘IL RES Lighting ISR.xls’ for more information. The average first year ISR was calculated weighted by the number of bulbs in each year’s survey.

\(^{781}\) The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; ‘New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report;, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2\(^{nd}\) and 3\(^{rd}\) year installations should be counted as part of those future program year savings.

\(^{782}\) In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.
deemed appropriate\(^{783}\) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below\(^{784}\):

<table>
<thead>
<tr>
<th>Utility</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComEd</td>
<td>1.05%</td>
</tr>
<tr>
<td>Ameren</td>
<td>6.55%</td>
</tr>
<tr>
<td>All other programs</td>
<td>0</td>
</tr>
</tbody>
</table>

Hours = Average hours of use per year

=2475 (6.78 hrs per day)\(^{785}\)

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- **Year 1 (Purchase Year) installs:** Characterized using assumptions provided above or evaluated assumptions if available.
- **Year 2 and 3 installs:** Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

```
For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen).

\[ \Delta kWH_{1st\ year\ installs} = \frac{(86 - 28)}{1000} \times 0.875 \times 2475 \]

= 125.6 kWh

\[ \Delta kWH_{2nd\ year\ installs} = \frac{(86 - 28)}{1000} \times 0.057 \times 2475 \]

= 8.2 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

\[ \Delta kWH_{3rd\ year\ installs} = \frac{(86 - 28)}{1000} \times 0.048 \times 2475 \]

= 6.9 kWh
```

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{CF} \]

Where:

\(^{783}\) Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

\(^{784}\) Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

\(^{785}\) Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
CF = Summer Peak Coincidence Factor for measure.
= 27.3\%^{786}

Other factors as defined above

For example, a 2 x 14W pin-based CFL fixture:

$$\Delta kW_{1st\ year} = \left(\frac{86 - 28}{1000}\right) \times 0.875 \times 0.273$$

$$= 0.0142\ kW$$

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**NATURAL GAS SAVINGS**

N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Life of the baseline bulb is assumed to be 0.4 years^{787} for exterior applications. Baseline bulb cost replacement is assumed to be $1.25.^{788}

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LRG-EFOX-V06-180101**

**REVIEW DEADLINE: 1/1/2020**

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^{786} Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

^{787} Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

^{788} Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
5.5.5 Interior Hardwired Compact Fluorescent Lamp (CFL) Fixture

**DESCRIPTION**

An ENERGY STAR lighting fixture wired for exclusive use with pin-based compact fluorescent lamps is installed in an interior residential setting. This measure could relate to either a fixture replacement or new installation (i.e. time of sale).

Federal legislation stemming from the Energy Independence and Security Act of 2007 required all general-purpose light bulbs between 40 and 100W to be approximately 30% more energy efficient than current incandescent bulbs. Production of 100W, standard efficacy incandescent lamps ends in 2012, followed by restrictions on 75W in 2013 and 60W and 40W in 2014. The baseline for this measure has therefore become bulbs (improved incandescent or halogen) that meet the new standard.

A provision in the EISA regulations requires that by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, in essence making the baseline equivalent to a current day CFL. Therefore the measure life (number of years that savings should be claimed) should be reduced once the assumed lifetime of the bulb exceeds 2020. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

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

**DEFINITION OF EFFICIENT EQUIPMENT**

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

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is a standard EISA qualified incandescent or halogen interior fixture as provided in the table provided in the Electric Energy Savings section.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected life of an interior fixture is 20 years. However due to the backstop provision in the Energy Independence and Security Act of 2007 that requires by January 1, 2020, all lamps meet efficiency criteria of at least 45 lumens per watt, the baseline replacement would become equivalent to a CFL in that year. The expected measure life for CFL fixtures installed in 2018 is therefore assumed to be 3 years. For bulbs installed in 2019, this would be reduced to 2 years and should be reduced each year.

**DEEMED MEASURE COST**

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

**LOADSHAPE**

- Loadshape R06 - Residential Indoor Lighting

---


790 Due to expected delay in clearing stock from retail outlets and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1%\(^{792}\) for Residential and in-unit Multi Family bulbs.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times (1 - \text{Leakage}) \times \text{Hours} \times \text{WHFe} \]

Where:

\(\text{WattsBase}\) = Based on lumens of CFL bulb and program year purchased:

<table>
<thead>
<tr>
<th>Minimum Lumens</th>
<th>Maximum Lumens</th>
<th>Incandescent Equivalent Post-EISA 2007 (Watts(_{\text{base}}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>5280</td>
<td>6209</td>
<td>300</td>
</tr>
<tr>
<td>3000</td>
<td>5279</td>
<td>200</td>
</tr>
<tr>
<td>2601</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td>1490</td>
<td>2600</td>
<td>72</td>
</tr>
<tr>
<td>1050</td>
<td>1489</td>
<td>53</td>
</tr>
<tr>
<td>750</td>
<td>1049</td>
<td>43</td>
</tr>
<tr>
<td>310</td>
<td>749</td>
<td>29</td>
</tr>
<tr>
<td>250</td>
<td>309</td>
<td>25</td>
</tr>
</tbody>
</table>

\(\text{WattsEE}\) = Actual wattage of CFL purchased

\(\text{ISR}\) = In Service Rate or the percentage of units rebated that get installed.

<table>
<thead>
<tr>
<th>Program</th>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale)</td>
<td>87.5%(^{793})</td>
<td>5.7%</td>
<td>4.8%</td>
<td>98.0%(^{794})</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9%(^{795})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{792}\) Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\(^{793}\) 1st year in service rate is based upon review of PY2-3 evaluations from ComEd (see ‘IL RES Lighting ISR.xls’ for more information. The average first year ISR was calculated weighted by the number of bulbs in the each year’s survey.

\(^{794}\) The 98% Lifetime ISR assumption is consistent with the assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type) based upon review of two evaluations:

- ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

\(^{795}\) In the absence of evaluation results for Direct Install Fixtures specifically, this is made consistent with the Direct Install CFL measure which is based upon review of the PY2 and PY3 ComEd Direct Install program surveys.
Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation or use deemed assumptions below:

- ComEd: 1.05%
- Ameren: 6.55%
- All other programs = 0

Hours = Average hours of use per year

<table>
<thead>
<tr>
<th>Installation Location</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential and in-unit Multi Family</td>
<td>759</td>
</tr>
</tbody>
</table>

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.06</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.04</td>
</tr>
</tbody>
</table>

### DEFERRED INSTALLS

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- **Year 1 (Purchase Year) installs:** Characterized using assumptions provided above or evaluated assumptions if available.
- **Year 2 and 3 installs:** Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

---

796 Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

797 Leakage rate is based upon TAC agreed 50% of the lamp leakage assumptions (based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see 'IL Leakage Rates_112016.xls' for more information)).

798 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

799 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8))). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling (“Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration”, 2009 Residential Energy Consumption Survey).

800 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).
For example, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen):

\[
\Delta kWh_{1st\ year\ installs} = \left(\frac{86 - 28}{1000}\right) \times 0.875 \times 759 \times 1.06 \\
= 40.8 \text{ kWh}
\]

\[
\Delta kWh_{2nd\ year\ installs} = \left(\frac{86 - 28}{1000}\right) \times 0.057 \times 759 \times 1.06 \\
= 2.7 \text{ kWh}
\]

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

\[
\Delta kWh_{3rd\ year\ installs} = \left(\frac{86 - 28}{1000}\right) \times 0.048 \times 759 \times 1.06 \\
= 2.2 \text{ kWh}
\]

**HEATING PENALTY**

If electric heated building:

\[
\Delta kWh = - \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{ISR} \times \text{Hours} \times \text{HF} / \eta_{\text{Heat}}
\]

Where:

- **HF** = Heating Factor or percentage of light savings that must be heated
  - 49\% for interior or unknown location
  - 0\% for unheated location
- \( \eta_{\text{Heat}} \) = Efficiency in COP of Heating equipment
  - actual. If not available use 803:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \text{COP}_{\text{Heat}} ) (COP Estimate) = ( \text{HSPF}/3.413 \times 0.85 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown(^{804})</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

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

802 This means that heating loads increase by 49\% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

803 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. Note efficiency should include duct losses. Defauls provided assume 15\% duct loss for heat pumps.

804 Calculation assumes 35\% Heat Pump and 65\% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50\% are units from before 2006 and 50\% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.
For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with 2.0 COP (including duct loss) Heat Pump:

\[
\Delta k\text{Wh}_{1\text{st year}} = - \frac{((86 - 28) / 1000) \times 0.875 \times 759 \times 0.49}{2.0} = -9.4 \text{ kWh}
\]

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

### Summer Coincident Peak Demand Savings

\[
\Delta kW = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{WHFd} \times \text{CF}
\]

Where:
- \(\text{WHFd}\) = Waste heat factor for demand to account for cooling savings from efficient lighting.

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.11805</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07806</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- \(\text{CF}\) = Summer Peak Coincidence Factor for measure.

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>CF807</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>7.1%</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>7.1%</td>
</tr>
</tbody>
</table>

Other factors as defined above

For example, a 14W pin-based CFL fixture:

\[
\Delta k\text{W}_{1\text{st year}} = \frac{((86 - 28) / 1000) \times 0.875 \times 1.11 \times 0.071}{2.0} = 0.004 \text{ kW}
\]

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

### Natural Gas Savings

\[
\Delta \text{Therms} = - \frac{((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412}{\eta\text{Heat}}
\]

Where:
- \(\text{HF}\) = Heating Factor or percentage of light savings that must be heated

---

805 The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to \(\text{WHFe}\) for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

806 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).

807 Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

808 Negative value because this is an increase in heating consumption due to the efficient lighting.
= 49% for interior or unknown location
= 0% for unheated location

0.03412 = Converts kWh to Therms
ηHeat = Efficiency of heating system
= 70%

For example, a 2 x 14W pin-based CFL fixture is purchased and installed in home with gas heat at 70% efficiency:

\[
\Delta \text{Therms}_{\text{1st year}} = -((86 - 28) / 1000) * 0.875 * 759 * 0.49 * 0.03412) / 0.7
\]

= -0.9 Therms

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

Life of the baseline bulb is assumed to be 1.3 years for interior applications. Baseline bulb cost replacement is assumed to be $1.25.

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs area actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-IFIX-V06-180101**

**REVIEW DEADLINE: 1/1/2020**

---

809 This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

810 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70
\]

811 Calculated by dividing assumed rated life of baseline bulb by hours of use. Assumed lifetime of EISA qualified Halogen/Incandescents is 1000 hours. The manufacturers are simply using a regular incandescent lamp with halogen fill gas rather than Halogen Infrared to meet the standard (as provided by G. Arnold, NEEP and confirmed by N. Horowitz at NRDC).

812 Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
5.5.6 LED Specialty Lamps

**DESCRIPTION**

This measure describes savings from a variety of specialty LED lamp types (including globe, decorative and downlights). This characterization assumes that the LED lamp or fixture is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used. This measure was developed to be applicable to the following program types: TOS, NC.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

To qualify for this measure the installed equipment must be an ENERGY STAR LED lamp or fixture. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf).

**DEFINITION OF BASELINE EQUIPMENT**

The baseline condition is assumed to be an incandescent/halogen lamp for all lamp types.

The baseline for the early replacement measure is the existing bulb being replaced.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

While LED rated lives are often 15,000 – 50,000 hours, all installations are assumed to be 10 years except for recessed downlight and track lights at 15 years. For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFL’s, the remaining life is 3,333 hours.

**DEEMED MEASURE COST**

The price of LED lamps is falling quickly. Where possible, the actual cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Year</th>
<th>Incandescent</th>
<th>LED</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recessed Downlight Luminaires</td>
<td>All</td>
<td>$4.00</td>
<td>$94.00</td>
<td>$90.00</td>
</tr>
<tr>
<td>Track Lights</td>
<td>All</td>
<td>$4.00</td>
<td>$60.00</td>
<td>$56.00</td>
</tr>
<tr>
<td>Directional</td>
<td>2017</td>
<td>$3.53</td>
<td>$6.24</td>
<td>$2.71</td>
</tr>
<tr>
<td></td>
<td>2018-2019</td>
<td></td>
<td>$5.18</td>
<td>$1.65</td>
</tr>
<tr>
<td>Decorative and Globe</td>
<td>2017</td>
<td>$1.60</td>
<td>$3.50</td>
<td>$1.90</td>
</tr>
<tr>
<td></td>
<td>2018-2019</td>
<td></td>
<td>$3.40</td>
<td>$1.66</td>
</tr>
</tbody>
</table>

---

813 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See “RESvC Split_112016.xls”.


815 Limited by persistence. NEEP EMV Emerging Technologies Research Report (December 2011)

816 Representing a third of the expected lamp lifetime.

817 Baseline and LED lamp costs for both directional and decorative and globe are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis. Recessed downlight and track light costs are based on VEIC review of a year’s worth of LED sales data through VEIC implemented programs and the retail cost averaged (see 2015 LED Sales Review.xls) and of price reports provided to Efficiency Vermont by a number of manufacturers and retailers. Baseline cost based on “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014.
**LOADSHAPE**

Loadshape R06 - Residential Indoor Lighting

Loadshape R07 - Residential Outdoor Lighting

**COINCIDENCE FACTOR**

Unlike standard lamps that could be installed in any room, certain types of specialty lamps are more likely to be found in specific rooms, which affects the coincident peak factor. Coincidence factors by bulb types are presented below.

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Peak CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>0.078</td>
</tr>
<tr>
<td>Dimmable</td>
<td>0.078</td>
</tr>
<tr>
<td>Interior reflector (incl. dimmable)</td>
<td>0.091</td>
</tr>
<tr>
<td>Exterior reflector</td>
<td>0.273</td>
</tr>
<tr>
<td>Unknown reflector</td>
<td>0.094</td>
</tr>
<tr>
<td>Candelabra base and candle medium and intermediate base</td>
<td>0.121</td>
</tr>
<tr>
<td>Bug light</td>
<td>0.273</td>
</tr>
<tr>
<td>Post light (&gt;100W)</td>
<td>0.273</td>
</tr>
<tr>
<td>Daylight</td>
<td>0.081</td>
</tr>
<tr>
<td>Plant light</td>
<td>0.081</td>
</tr>
<tr>
<td>Globe</td>
<td>0.075</td>
</tr>
<tr>
<td>Vibration or shatterproof</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard Spiral &gt;=2601 lumens, Residential, Multi-family in unit</td>
<td>0.071</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, unknown</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, exterior</td>
<td>0.273</td>
</tr>
<tr>
<td>Specialty - Generic</td>
<td>0.081</td>
</tr>
</tbody>
</table>

**Algorithm**

**CALCULATION OF SAVINGS**

**Electric Energy Savings**

\[ \Delta \text{kWh} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times (1 - \text{Leakage}) \times \text{Hours} \times \text{WHFe} \]

Where:

- **Watts\text{base}** = Input wattage of the existing or baseline system. Reference the table below for default values.

EISA exempt bulb types:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Watts\text{Base}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Spirals &gt;=2601</td>
<td>2601</td>
<td>2999</td>
<td>150</td>
</tr>
</tbody>
</table>

---

818 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
819 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.
820 Ibid
### LED Specialty Lamps

#### Bulb Type

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Watts/Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Way</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Way</td>
<td>250</td>
<td>449</td>
<td>25</td>
</tr>
<tr>
<td>3-Way</td>
<td>450</td>
<td>799</td>
<td>40</td>
</tr>
<tr>
<td>3-Way</td>
<td>800</td>
<td>1099</td>
<td>60</td>
</tr>
<tr>
<td>3-Way</td>
<td>1100</td>
<td>1599</td>
<td>75</td>
</tr>
<tr>
<td>3-Way</td>
<td>1600</td>
<td>1999</td>
<td>100</td>
</tr>
<tr>
<td>3-Way</td>
<td>2000</td>
<td>2549</td>
<td>125</td>
</tr>
<tr>
<td>3-Way</td>
<td>2550</td>
<td>2999</td>
<td>150</td>
</tr>
<tr>
<td>Globe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe</td>
<td>90</td>
<td>179</td>
<td>10</td>
</tr>
<tr>
<td>Globe</td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td>Globe</td>
<td>250</td>
<td>349</td>
<td>25</td>
</tr>
<tr>
<td>Globe</td>
<td>350</td>
<td>749</td>
<td>40</td>
</tr>
<tr>
<td>Decorative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decorative</td>
<td>70</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td>Decorative</td>
<td>90</td>
<td>149</td>
<td>15</td>
</tr>
<tr>
<td>Decorative</td>
<td>150</td>
<td>299</td>
<td>25</td>
</tr>
<tr>
<td>Decorative</td>
<td>300</td>
<td>749</td>
<td>40</td>
</tr>
<tr>
<td>Globe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Globe</td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td>Globe</td>
<td>250</td>
<td>349</td>
<td>25</td>
</tr>
<tr>
<td>Globe</td>
<td>350</td>
<td>499</td>
<td>40</td>
</tr>
<tr>
<td>Globe</td>
<td>500</td>
<td>1049</td>
<td>60</td>
</tr>
<tr>
<td>Decorative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decorative</td>
<td>70</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td>Decorative</td>
<td>90</td>
<td>149</td>
<td>15</td>
</tr>
<tr>
<td>Decorative</td>
<td>150</td>
<td>299</td>
<td>25</td>
</tr>
<tr>
<td>Decorative</td>
<td>300</td>
<td>499</td>
<td>40</td>
</tr>
<tr>
<td>Decorative</td>
<td>500</td>
<td>1049</td>
<td>60</td>
</tr>
</tbody>
</table>

### Directional Lamps -

For Directional R, BR, and ER lamp types\(^\text{821}\):

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Watts/Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>420</td>
<td>472</td>
<td>40</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>473</td>
<td>524</td>
<td>45</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>525</td>
<td>714</td>
<td>50</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>715</td>
<td>937</td>
<td>65</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>938</td>
<td>1259</td>
<td>75</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>1260</td>
<td>1399</td>
<td>90</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>1400</td>
<td>1739</td>
<td>100</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>1740</td>
<td>2174</td>
<td>120</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>2175</td>
<td>2624</td>
<td>150</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>2625</td>
<td>2999</td>
<td>175</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>3000</td>
<td>4500</td>
<td>200</td>
</tr>
<tr>
<td>R, ER, BR with medium screw bases w/ diameter &gt;2.25&quot; (*see exceptions below)</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
</tbody>
</table>

\(^{821}\) From pg 11 of the Energy Star Specification for lamps v1.1
### LED Specialty Lamps

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Wattsbase</th>
</tr>
</thead>
<tbody>
<tr>
<td>*R, BR, and ER with medium screw bases w/</td>
<td>450</td>
<td>499</td>
<td>45</td>
</tr>
<tr>
<td>diameter &lt;=2.25”</td>
<td>500</td>
<td>649</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>1199</td>
<td>65</td>
</tr>
<tr>
<td>*ER30, BR30, BR40, or ER40</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>499</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>500</td>
<td>649</td>
<td>50</td>
</tr>
<tr>
<td>*BR30, BR40, or ER40</td>
<td>650</td>
<td>1419</td>
<td>65</td>
</tr>
<tr>
<td>*R20</td>
<td>400</td>
<td>449</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>450</td>
<td>719</td>
<td>45</td>
</tr>
<tr>
<td>*All reflector lamps below lumen ranges</td>
<td>200</td>
<td>299</td>
<td>20</td>
</tr>
<tr>
<td>specified above</td>
<td>300</td>
<td>399</td>
<td>30</td>
</tr>
</tbody>
</table>

Directional lamps are exempt from EISA regulations.

For PAR, MR, and MRX Lamps Types:

For these highly focused directional lamp types, it is necessary to have Center Beam Candle Power (CBCP) and beam angle measurements to accurately estimate the equivalent baseline wattage. The formula below is based on the Energy Star Center Beam Candle Power tool. 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.

\[
Watts_{base} = 375.1 - 4.355(D) - \sqrt{227,800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D \times BA) + 14.69(BA^2) - 16,720 \times \ln(CBCP)}
\]

Where:

- \(D\) = Bulb diameter (e.g. for PAR20 \(D = 20\))
- \(BA\) = Beam angle
- \(CBCP\) = Center beam candle power

The result of the equation above should be rounded DOWN to the nearest wattage established by Energy Star:

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Permitted Wattages</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>20, 35, 40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>30S</td>
<td>40, 45, 50, 60, 75</td>
</tr>
<tr>
<td>30L</td>
<td>50, 75</td>
</tr>
<tr>
<td>38</td>
<td>40, 45, 50, 55, 60, 65, 75, 85, 90, 100, 120, 150, 250</td>
</tr>
</tbody>
</table>

---


823 The Energy Star Center Beam Candle Power tool does not accurately model baseline wattages for lamps with certain bulb characteristic combinations – specifically for lamps with very high CBCP.
EISA non-exempt bulb types:

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Lower Lumen Range</th>
<th>Upper Lumen Range</th>
<th>Incandescent Equivalent Post-EISA 2007 (WattsBase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimmable Twist, Globe (less than 5&quot; in diameter and &gt; 749 lumens), candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt; 1049 lumens), Intermediate Base Lamps (&gt; 749 lumens)</td>
<td>310 to 750</td>
<td>749 to 1049</td>
<td>29 to 43</td>
</tr>
<tr>
<td></td>
<td>1050</td>
<td>1489</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>1490</td>
<td>2600</td>
<td>72</td>
</tr>
</tbody>
</table>

WattSee = Actual wattage of LED purchased / installed.

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

<table>
<thead>
<tr>
<th>Program</th>
<th>Bulb Type</th>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale)</td>
<td>Recessed downlight luminaries and Track Lights</td>
<td>100%824</td>
<td></td>
<td></td>
<td>98.0%826</td>
</tr>
<tr>
<td>All other lamps</td>
<td></td>
<td>93.5%825</td>
<td>2.4%</td>
<td>2.1%</td>
<td></td>
</tr>
<tr>
<td>Direct Install</td>
<td>All lamps</td>
<td>96.9%827</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate828) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below829:

---

824 NEEP EMV Emerging Technologies Research Report (December 2011)
825 1st year in service rate is based upon analysis of ComEd PY7 and PY8 intercept data (see 'IL RES Lighting ISR_112016.xls' for more information).
826 The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations: ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report:, Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.
827 Consistent with assumption for standard CFLs (in the absence of evidence that it should be different for this bulb type).
828 Based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.
829 Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.
829 Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see ‘IL Leakage Rates_112016.xls’ for more information).
ComEd: 2.1%
Ameren: 13.1%
All other programs = 0

Hours = Average hours of use per year

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Annual hours of use (HOU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>850</td>
</tr>
<tr>
<td>Dimmable</td>
<td>850</td>
</tr>
<tr>
<td>Interior reflector (incl. dimmable)</td>
<td>861</td>
</tr>
<tr>
<td>Exterior reflector</td>
<td>2475</td>
</tr>
<tr>
<td>Unknown reflector</td>
<td>891</td>
</tr>
<tr>
<td>Candelabra base and candle medium and intermediate base</td>
<td>1190</td>
</tr>
<tr>
<td>Bug light</td>
<td>2475</td>
</tr>
<tr>
<td>Post light (&gt;100W)</td>
<td>2475</td>
</tr>
<tr>
<td>Daylight</td>
<td>847</td>
</tr>
<tr>
<td>Plant light</td>
<td>847</td>
</tr>
<tr>
<td>Globe</td>
<td>639</td>
</tr>
<tr>
<td>Vibration or shatterproof</td>
<td>847</td>
</tr>
<tr>
<td>Standard Spiral &gt;2601 lumens, Residential, Multi Family in-unit</td>
<td>759</td>
</tr>
<tr>
<td>Standard Spiral &gt;2601 lumens, unknown</td>
<td>847</td>
</tr>
<tr>
<td>Standard Spiral &gt;2601 lumens, Exterior</td>
<td>2475</td>
</tr>
<tr>
<td>Specialty – Generic Interior</td>
<td>847</td>
</tr>
<tr>
<td>Specialty – Generic Exterior</td>
<td>2475</td>
</tr>
</tbody>
</table>

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.06</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.04</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium

---

830 Hours of use by specialty bulb type calculated using the average hours of use in locations or rooms where each type of specialty bulb is most commonly found. Values for Reflector, Decorative and Globe are taken directly from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. All other hours have been updated based on the room specific hours of use from the PY5/PY6 logger study.

831 The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8))). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP) and 66% of homes in Illinois having central cooling (“Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration”, 2009 Residential Energy Consumption Survey)

832 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)
screw base, diameter >2.5", installed in single family interior location:
\[ \Delta kWh = \left( \frac{45 - 13}{1000} \right) \times 0.935 \times 861 \times 1.06 \]
\[ = 27.3 \text{ kWh} \]

**Mid Life Baseline Adjustment**

For non-exempt lamps, an appropriate baseline adjustment should be included to account for the 2020 EISA backstop provision making replacement baseline lamps meet 45 lumens/watt. Due to expected delay in clearing retail inventory and to account for the operating life of a halogen incandescent potentially spanning over 2020, this shift is assumed not to occur until 2021.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[ \Delta kWh = - \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{HF} / \eta_{\text{Heat}} \]

Where:

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

= 49%\(^{834}\) for interior or unknown location

= 0% for exterior location

\( \eta_{\text{Heat}} \) = Efficiency in COP of Heating equipment

= Actual. If not available use: \(^{835}\):

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP(_{HEAT}) (COP Estimate) = (HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown(^{836})</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

\(^{833}\) Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{834}\) This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

\(^{835}\) 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. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

\(^{836}\) Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.
For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5", installed in single family interior location with a 2016 heat pump:

\[ \Delta \text{kWh} = - \frac{(45 - 13)}{1000} \times 0.935 \times 861 \times 0.49 \times 2.04 \]
\[ = - 6.19 \text{kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{WHFd} \times \text{CF} \]

Where:

\[ \text{WHFd} = \text{Waste heat factor for demand to account for cooling savings from efficient lighting.} \]

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.11</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[ \text{CF} = \text{Summer Peak Coincidence Factor for measure, see above for values.} \]

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Peak CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>0.078</td>
</tr>
<tr>
<td>Dimmable</td>
<td>0.078</td>
</tr>
<tr>
<td>Interior reflector (incl. dimmable)</td>
<td>0.091</td>
</tr>
<tr>
<td>Exterior reflector</td>
<td>0.273</td>
</tr>
<tr>
<td>Unknown reflector</td>
<td>0.094</td>
</tr>
<tr>
<td>Candelabra base and candle medium and intermediate base</td>
<td>0.121</td>
</tr>
<tr>
<td>Bug light</td>
<td>0.273</td>
</tr>
<tr>
<td>Post light (&gt;100W)</td>
<td>0.273</td>
</tr>
<tr>
<td>Daylight</td>
<td>0.081</td>
</tr>
<tr>
<td>Plant light</td>
<td>0.081</td>
</tr>
<tr>
<td>Globe</td>
<td>0.075</td>
</tr>
<tr>
<td>Vibration or shatterproof</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard Spiral &gt;= 2601 lumens, Residential, Multi-family in unit</td>
<td>0.071</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, unknown</td>
<td>0.081</td>
</tr>
<tr>
<td>Standard spirals &gt;= 2601 lumens, exterior</td>
<td>0.273</td>
</tr>
<tr>
<td>Specialty - Generic</td>
<td>0.081</td>
</tr>
</tbody>
</table>

Other factors as defined above

837 The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

838 As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

839 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

840 Based on average of bedroom, dining room, office and living room results from the lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

841 Ibid
**Natural Gas Savings**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

\[ \Delta \text{therms} = - \left( \frac{(Watts_{Base} - Watts_{EE})}{1000} \right) \times ISR \times Hours \times HF \times 0.03412 / \eta_{\text{Heat}} \]

Where:

- \(HF\) = Heating factor, or percentage of lighting savings that must be replaced by heating system.
  - 49% \[842\] for interior or unknown location
  - 0% for exterior location
- 0.03412 = Converts kWh to Therms
- \(\eta_{\text{Heat}}\) = Average heating system efficiency.
  - 0.70 \[843\]
- Other factors as defined above

For example, a 13W PAR20 LED is installed in place of a 750 lumen PAR20 incandescent screw-in lamp with medium screw base, diameter >2.5", installed in single family interior location:

\[ \Delta kW = \left( \frac{(45 - 13)}{1000} \right) \times 0.935 \times 1.11 \times 0.091 \]
\[ = 0.0030 \text{ kW} \]

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

For those bulb types exempt from EISA (except for reflectors) the following O&M assumptions should be used: Life of the baseline bulb is assumed to be 1.32 year\[844\]; baseline replacement cost is assumed to be $4.0.

For reflectors the life of the baseline bulb and the cost of its replacement is presented in the following table:

---

\[842\] Average result from REMRate modeling of several different configurations and IL locations of homes

\[843\] This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey).

In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70\]

\[844\] Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32
### 5.5.6 LED Specialty Lamps

#### Lamp Type Analysis

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Baseline Lamp Life (hours)</th>
<th>Baseline Life (Single Family and in unit Multifamily - 1010 hours)</th>
<th>Baseline Replacement Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAR20, PAR30, PAR38 screw-in lamps</td>
<td>2000</td>
<td>2.0</td>
<td>$4.00</td>
</tr>
<tr>
<td>MR16/ PAR16 pin-based lamps</td>
<td>2000</td>
<td>2.0</td>
<td>$3.00</td>
</tr>
<tr>
<td>Recessed downlight luminaries</td>
<td>2000</td>
<td>2.0</td>
<td>$4.00</td>
</tr>
<tr>
<td>Track lights</td>
<td>2000</td>
<td>2.0</td>
<td>$4.00</td>
</tr>
</tbody>
</table>

For non-exempt EISA bulb types defined above, in order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

Bulb replacement costs assumed in the O&M calculations are provided below.\(^{845}\)

<table>
<thead>
<tr>
<th>Year</th>
<th>EISA Compliant Bulb Type</th>
<th>NPV of replacement costs for period</th>
<th>Levelized annual replacement cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>Dimmable Twist, Globe (less than 5&quot; in diameter and &gt; 749 lumens), candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt;1049 lumens), Intermediate Base Lamps (&gt;749 lumens)</td>
<td>$2.86</td>
<td>$0.29</td>
</tr>
<tr>
<td>2019</td>
<td>Dimmable Twist, Globe (less than 5&quot; in diameter and &gt; 749 lumens), candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt;1049 lumens), Intermediate Base Lamps (&gt;749 lumens)</td>
<td>$2.86</td>
<td>$0.29</td>
</tr>
<tr>
<td>2020</td>
<td>Dimmable Twist, Globe (less than 5&quot; in diameter and &gt; 749 lumens), candle (shapes B, BA, CA &gt; 749 lumens), Candelabra Base Lamps (&gt;1049 lumens), Intermediate Base Lamps (&gt;749 lumens)</td>
<td>$2.86</td>
<td>$0.29</td>
</tr>
</tbody>
</table>

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below.\(^{846}\)

It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs are actually in service and so should be multiplied by the appropriate ISR.

---

\(^{845}\) Baseline costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

\(^{846}\) Assumed consistent with LED cost.

\(^{847}\) Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.

\(^{848}\) See “Specialty LED EISA compliant O&M Calc.xlsx” for calculation.
MEASURE CODE: RS-LTG-LEDD-V07-180101

REVIEW DEADLINE: 1/1/2020
5.5.7 LED Exit Signs

DESCRIPTION
This measure characterizes the savings associated with installing a Light Emitting Diode (LED) exit sign in place of a fluorescent or incandescent exit sign in a MultiFamily building. Light Emitting Diode exit signs have a string of very small, typically red or green, glowing LEDs arranged in a circle or oval. The LEDs may also be arranged in a line on the side, top or bottom of the exit sign. LED exit signs provide the best balance of safety, low maintenance, and very low energy usage compared to other exit sign technologies.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT
The efficient equipment is assumed to be an exit sign illuminated by LEDs.

DEFINITION OF BASELINE EQUIPMENT
The baseline equipment is assumed to be a fluorescent or incandescent model.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT
The measure life is assumed to be 16 years\textsuperscript{849}.

DEEMED MEASURE COST
The incremental cost for this measure is assumed to be $30\textsuperscript{850}.

LOADSHAPE
Loadshape C53 - Flat

COINCIDENCE FACTOR
The summer peak coincidence factor for this measure is assumed to be 100\%\textsuperscript{851}.

\begin{center}
\textbf{Algorithm}
\end{center}

\textbf{CALCULATION OF SAVINGS}

\textbf{ELECTRIC ENERGY SAVINGS}
\[ \Delta \text{kWh} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{HOURS} \times \text{WHF} \]

Where:
\[ \text{WattsBase} = \text{Actual wattage if known, if unknown assume the following:} \]

\begin{itemize}
\item \textsuperscript{850} NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr.
\item \textsuperscript{851} Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.
\end{itemize}
<table>
<thead>
<tr>
<th>Baseline Type</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>35W\textsuperscript{52}</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>11W\textsuperscript{53}</td>
</tr>
<tr>
<td>Unknown (e.g. time of sale)</td>
<td>11W</td>
</tr>
</tbody>
</table>

Watts\textsubscript{EE} = Actual wattage if known, if unknown assume 2W\textsuperscript{54}

HOURS = Annual operating hours

= 8766

WH\textsubscript{F}e = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04\textsuperscript{55} for multi family buildings

Default if replacing incandescent fixture

\[ \Delta kWH = \frac{(35 - 2)/1000 \times 8766 \times 1.04}{1000} = 301 \text{ kWh} \]

Default if replacing fluorescent fixture

\[ \Delta kWH = \frac{(11 - 2)/1000 \times 8766 \times 1.04}{1000} = 82 \text{ kWh} \]

**HEATING PENALTY**

If electric heated building (if heating fuel is unknown assume gas, see Natural Gas section):

\[ \Delta kWh\textsuperscript{56} = - \left( \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \right) \times \text{Hours} \times HF / \eta\text{Heat} \]

Where:

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

\[ = 49\%\textsuperscript{57} \]

\[ \eta\text{Heat} = \text{Efficiency in COP of Heating equipment} \]

\[ = \text{Actual. If not available use:}\textsuperscript{58} \]

\[ \text{Note efficiency should include duct} \]

\textsuperscript{52} Based on review of available product.


\textsuperscript{55} The value is estimated at 1.04 (calculated as 1 + (0.45*(0.27 / 2.8)). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 3.1 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) (from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP and estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average)

\textsuperscript{56} Negative value because this is an increase in heating consumption due to the efficient lighting.

\textsuperscript{57} This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.

\textsuperscript{58} These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate. Note efficiency should include duct
### LED Exit Signs

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP&lt;sub&gt;HEAT&lt;/sub&gt; (COP Estimate) = (HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown&lt;sup&gt;859&lt;/sup&gt;</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

For example, a 2.0COP (including duct loss) Heat Pump heated building:

If incandescent fixture:  
\[ \Delta kWH = -\frac{(35 - 2)}{1000} \times 8766 \times 0.49 \times 0.5 \]
\[ = -71 \text{ kWh} \]

If fluorescent fixture  
\[ \Delta kWH = -\frac{(11 - 2)}{1000} \times 8766 \times 0.49 \times 0.5 \]
\[ = -19 \text{ kWh} \]

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[ \Delta kW = ((WattsBase - WattsEE) / 1000) \times \text{WHF}_d \times \text{CF} \]

Where:

\[ \text{WHF}_d = \text{Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings.} \]
\[ = 1.07^{860} \text{ for multi family buildings} \]

\[ \text{CF} = \text{Summer Peak Coincidence Factor for measure} \]
\[ = 1.0 \]

Default if incandescent fixture  
\[ \Delta kW = (35 - 2)/1000 \times 1.07 \times 1.0 \]
\[ = 0.035 \text{ kW} \]

Default if fluorescent fixture  
\[ \Delta kW = (11 - 2)/1000 \times 1.07 \times 1.0 \]
\[ = 0.0096 \text{ kW} \]

### NATURAL GAS SAVINGS

Heating penalty if Natural Gas heated building, or if heating fuel is unknown.

\[ \Delta \text{therms} = -((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{Hours} \times \text{HF} \times 0.03412 \times \eta_{\text{Heat}} \]

---

<sup>859</sup> Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see "HC6.9 Space Heating in Midwest Region.xls", using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

<sup>860</sup> The value is estimated at 1.11 (calculated as 1 + (0.45 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.
Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.
    = 49% \(^{861}\)

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.
    = 0.70 \(^{862}\)

Other factors as defined above

Default if incandescent fixture

\[
\Delta\text{therms} = - \frac{(((35 - 2)/1000) * 8766 * 0.49 * 0.03412)}{0.70}
\]

\[= -6.9 \text{ therms}\]

Default if fluorescent fixture

\[
\Delta\text{therms} = - \frac{(((11 - 2)/1000) * 8766 * 0.49 * 0.03412)}{0.70}
\]

\[= -1.9 \text{ therms}\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

The annual O&M Cost Adjustment savings should be calculated using the following component costs and lifetimes.

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost</th>
<th>Life (yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp</td>
<td>$7.00(^{863})</td>
<td>1.37 years(^{864})</td>
</tr>
</tbody>
</table>

**MEASURE CODE: RS-LTG-LEDE-V02-180101**

**REVIEW DEADLINE: 1/1/2019**

\(^{861}\) Average result from REMRate modeling of several different configurations and IL locations of homes

\(^{862}\) This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[
(0.24*0.92) + (0.76*0.8) * (1-0.15) = 0.70
\]

\(^{863}\) Consistent with assumption for a Standard CFL bulb with an estimated labor cost of $4.50 (assuming $18/hour and a task time of 15 minutes).

\(^{864}\) Assumes a lamp life of 12,000 hours and 8766 run hours 12000/8766 = 1.37 years.
5.5.8 LED Screw Based Omnidirectional Bulbs

**DESCRIPTION**

This characterization provides savings assumptions for LED Screw Based Omnidirectional (e.g. A-Type lamps) lamps within the residential and multifamily sectors. This characterization assumes that the LED lamp or fixture is installed in a residential location. Where the implementation strategy does not allow for the installation location to be known (e.g. an upstream retail program) a deemed split of 95% Residential and 5% Commercial assumptions should be used.

This measure was developed to be applicable to the following program types: TOS, NC, EREP, KITS.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

In order for this characterization to apply, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.0 becomes effective on 1/2/2017 (https://www.energystar.gov/products/spec/lamps_specification_version_2_0.pdf).

**DEFINITION OF BASELINE EQUIPMENT**

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EIAS) will require all general-purpose light bulbs between 40 watts and 100 watts to have ~30% increased efficiency, essentially phasing out standard incandescent technology. In 2012, the 100 w lamp standards apply; in 2013 the 75 w lamp standards will apply, followed by restrictions on the 60 w and 40 w lamps in 2014. Since measures installed under this TRM all occur after 2014, baseline equipment are the values after EISA. These are shown in the baseline table below.

The baseline for the early replacement measure is the existing bulb being replaced.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The deemed measure life is 6.1 years for exterior application. For all other applications, lifetimes are capped at 10 years.

For early replacement measures, if replacing a halogen or incandescent bulb, the remaining life is assumed to be 333 hours. For CFL’s, the remaining life is 3,333 hours.

**DEEMED MEASURE COST**

The price of LED lamps is falling quickly. Where possible, the actual LED lamp cost should be used and compared to the baseline cost provided below. If the incremental cost is unknown, assume the following:

<table>
<thead>
<tr>
<th>Year</th>
<th>EISA Compliant</th>
<th>LED-A</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>$1.25</td>
<td>$3.21</td>
<td>$1.96</td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td>$3.21</td>
<td>$1.96</td>
</tr>
</tbody>
</table>

---

865 RES v C&I split is based on a weighted (by sales volume) average of ComEd PY6, PY7 and PY8 and Ameren PY5, PY6 and PY8 in store intercept survey results. See ‘RESvCISplit_112016.xls’.

866 ENERGY STAR v2.0 requires omnidirectional LED bulbs to be rated for at least 15,000 hours. 15000/2475 (exterior hours of use) = 6.1 years.


868 Representing a third of the expected lamp lifetime.

869 Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
5.5.8 LED Screw Based Omnidirectional Bulbs

<table>
<thead>
<tr>
<th>Year</th>
<th>EISA Compliant Halogen</th>
<th>LED-A</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>$3.11</td>
<td></td>
<td>$1.86</td>
</tr>
</tbody>
</table>

LOADSHAPE

Loadshape R06 – Residential Indoor Lighting

Loadshape R07 – Residential Outdoor Lighting

COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1% for Residential and in-unit Multi Family bulbs, 27.3% for exterior bulbs and 8.1% for unknown.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta kWh = \left(\frac{Watts_{\text{base}} - Watts_{\text{EE}}}{1000}\right) \times ISR \times (1 - \text{Leakage}) \times \text{Hours} \times WHF_e
\]

Where:

- Watts_{\text{base}} = Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.
- Watts_{\text{EE}} = Actual wattage of LED purchased / installed. If unknown, use default provided below:

LED New and Baseline Assumptions Table

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5280</td>
<td>6209</td>
<td>5745</td>
<td>72.9</td>
<td>300.0</td>
<td>227.1</td>
<td>300.0</td>
<td>227.1</td>
</tr>
<tr>
<td>3000</td>
<td>5279</td>
<td>4140</td>
<td>52.5</td>
<td>200.0</td>
<td>147.5</td>
<td>200.0</td>
<td>147.5</td>
</tr>
<tr>
<td>2601</td>
<td>2999</td>
<td>2800</td>
<td>35.5</td>
<td>150.0</td>
<td>114.5</td>
<td>150.0</td>
<td>114.5</td>
</tr>
<tr>
<td>1490</td>
<td>2600</td>
<td>2045</td>
<td>26.0</td>
<td>72.0</td>
<td>46.0</td>
<td>45.4</td>
<td>19.5</td>
</tr>
<tr>
<td>1050</td>
<td>1489</td>
<td>1270</td>
<td>16.1</td>
<td>53.0</td>
<td>36.9</td>
<td>28.2</td>
<td>12.1</td>
</tr>
<tr>
<td>750</td>
<td>1049</td>
<td>900</td>
<td>11.4</td>
<td>43.0</td>
<td>31.6</td>
<td>20.0</td>
<td>8.6</td>
</tr>
<tr>
<td>310</td>
<td>749</td>
<td>530</td>
<td>6.7</td>
<td>29.0</td>
<td>22.3</td>
<td>11.8</td>
<td>5.0</td>
</tr>
<tr>
<td>250</td>
<td>309</td>
<td>280</td>
<td>3.5</td>
<td>25.0</td>
<td>21.5</td>
<td>25.0</td>
<td>21.5</td>
</tr>
</tbody>
</table>

ISR = In Service Rate, the percentage of units rebated that are actually in service.

\(^{870}\) Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

\(^{871}\) Based on ENERGY STAR V2.0 specs – for omnidirectional <90CRI: 80 lm/W and for omnidirectional >=90 CRI: 70 lm/W. To weight these two criteria, the ENERGY STAR qualified list was reviewed and found to contain 87.8% lamps <90CRI and 12.2% >=90CRI.

\(^{872}\) Calculated as 45lm/W for all EISA non-exempt bulbs.
### Table: LED Screw Based Omnidirectional Bulbs

<table>
<thead>
<tr>
<th>Program</th>
<th>Weighted Average 1st year In Service Rate (ISR)</th>
<th>2nd year Installations</th>
<th>3rd year Installations</th>
<th>Final Lifetime In Service Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail (Time of Sale)</td>
<td>89.9%(^{873})</td>
<td>4.3%</td>
<td>3.7%</td>
<td>98.0%(^{874})</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9%(^{875})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Efficiency Kits(^{876})</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFL Distribution(^{877})</td>
<td>59%</td>
<td>13%</td>
<td>11%</td>
<td>83%</td>
</tr>
<tr>
<td>School Kits(^{878})</td>
<td>61%</td>
<td>13%</td>
<td>11%</td>
<td>86%</td>
</tr>
<tr>
<td>Direct Mail Kits(^{879})</td>
<td>66%</td>
<td>14%</td>
<td>12%</td>
<td>93%</td>
</tr>
</tbody>
</table>

**Leakage**

- Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate\(^{880}\)) of the Utility Jurisdiction.

**KITS programs**

- **Upstream (TOS) Lighting programs** = Determined through evaluation
- **or use deemed assumptions below**\(^{881}\):
  - ComEd: 2.1%
  - Ameren: 13.1%
  - All other programs = 0

**Hours**

- Average hours of use per year

\(^{873}\) 1st year in service rate is based upon analysis of ComEd PY7 and PY8 and Ameren PY8 intercept data (see ‘IL RES Lighting ISR_112016.xls’ for more information).

\(^{874}\) The 98% Lifetime ISR assumption is based upon the standard CFL measure in the absence of any better reference. This value is based upon review of two evaluations:
  - ‘Nexus Market Research, RLW Analytics and GDS Associates study; “New England Residential Lighting Markdown Impact Evaluation, January 20, 2009’ and ‘KEMA Inc, Feb 2010, Final Evaluation Report: Upstream Lighting Program, Volume 1.’ This implies that only 2% of bulbs purchased are never installed. The second and third year installations are based upon Ameren analysis of the Californian KEMA study showing that 54% of future installs occur in year 2 and 46% in year 3. The 2nd and 3rd year installations should be counted as part of those future program year savings.

\(^{875}\) Based upon Standard CFL assumption in the absence of better data, and is based upon review of the PY2 and PY3 ComEd Direct Install program surveys. This value includes bulb failures in the 1st year to be consistent with the Commission approval of annualization of savings for first year savings claims. ComEd PY2 All Electric Single Family Home Energy Performance Tune-Up Program Evaluation, Navigant Consulting, December 21, 2010.

\(^{876}\) In Service Rates provided are for the bulb within a kit only. Given the significant differences in program design and the level of education provided through Efficiency Kits programs, the evaluators should apply the ISR estimated through evaluations (either past evaluations or the current program year evaluation) of the specific Efficiency Kits program. In cases where program-specific evaluation results for an ISR are unavailable, the default ISR values for Efficiency Kits provide may be used.

\(^{877}\) Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

\(^{878}\) Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

\(^{879}\) Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.

\(^{880}\) Leakage in is only appropriate to credit to IL utility program savings if it is reasonably expected that the IL utility program marketing efforts played an important role in influencing customer to purchase the light bulbs. Furthermore, consideration that such customers might be free riders should be addressed. If leakage in is assessed, efforts should be made to ensure no double counting of savings occurs if the evaluation is estimating both leakage in and spillover savings of light bulbs.

\(^{881}\) Leakage rate is based upon review of PY6-8 evaluations from ComEd and PY5,6 and 8 for Ameren (see ‘IL Leakage Rates_112016.xls’ for more information).
### Installation Location

<table>
<thead>
<tr>
<th>Installation Location</th>
<th>Hours&lt;sup&gt;882&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential and in-unit Multi Family</td>
<td>759</td>
</tr>
<tr>
<td>Exterior</td>
<td>2475</td>
</tr>
<tr>
<td>Unknown</td>
<td>847</td>
</tr>
</tbody>
</table>

#### WHFe

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe&lt;sup&gt;883&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.06</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.04</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### Mid Life Baseline Adjustment

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. Since the baseline bulb changes over time (except for <300 and 2600+ lumen lamps) the annual savings claim must be reduced within the life of the measure to account for this baseline shift.

For example, for 60W equivalent bulbs installed in 2018, the full savings (as calculated above in the Algorithm) should be claimed for the first three years, but a reduced annual savings (calculated energy savings above multiplied by the adjustment factor in the table below) claimed for the remainder of the measure life.

<table>
<thead>
<tr>
<th>Minimum Lumens</th>
<th>Maximum Lumens</th>
<th>LED Wattage (WattsEE)</th>
<th>Delta Watts 2014-2019 (WattsEE)</th>
<th>Delta Watts Post 2020 (WattsEE)</th>
<th>Mid Life adjustment (made from 01/2021) to first year savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1490</td>
<td>2600</td>
<td>26.0</td>
<td>46.0</td>
<td>19.5</td>
<td>42.3%</td>
</tr>
<tr>
<td>1050</td>
<td>1489</td>
<td>16.1</td>
<td>36.9</td>
<td>12.1</td>
<td>32.8%</td>
</tr>
<tr>
<td>750</td>
<td>1049</td>
<td>11.4</td>
<td>31.6</td>
<td>8.6</td>
<td>27.1%</td>
</tr>
<tr>
<td>310</td>
<td>749</td>
<td>6.7</td>
<td>22.3</td>
<td>5.0</td>
<td>22.6%</td>
</tr>
</tbody>
</table>

<sup>882</sup> Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

<sup>883</sup> The value is estimated at 1.06 (calculated as 1 + (0.66*(0.27 / 2.8))). Based on cooling loads decreasing by 27% of the lighting savings (average result from REMRate modeling of several different configurations and IL locations of homes), assuming typical cooling system operating efficiency of 2.8 COP (starting from standard assumption of SEER 10.5 central AC unit, converted to 9.5 EER using algorithm (-0.02 * SEER2) + (1.12 * SEER) from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder), converted to COP = EER/3.412 = 2.8COP and 66% of homes in Illinois having central cooling ("Table HC7.9  Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey).

<sup>884</sup> As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1  Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence compared to US average).
For example, an 8W LED lamp, 450 lumens, is installed in the interior of a home. The customer purchased the lamp through an upstream program:

\[
\Delta \text{kWh} = \left(\frac{29-6.7}{1000}\right) \times 847 \times 1.06 \times 0.899
\]

= 18.0 kWh

This value should be claimed for three years, i.e. 2018-2020, but from 2021 until the end of the measure life for that same bulb, savings should be reduced to \((18.0 \times 0.226) = 4.1\) kWh for the remainder of the measure life. Note these adjustments should be applied to kW and fuel impacts as well.

Note for early replacement measures an additional baseline shift accounting for the replacement of the existing unit with a new baseline lamp should be accounted for.

**DEFERRED INSTALLS**

As presented above, the characterization assumes that a percentage of bulbs purchased are not installed until Year 2 and Year 3 (see ISR assumption above). The Illinois Technical Advisory Committee has determined the following methodology for calculating the savings of these future installs.

- **Year 1 (Purchase Year) installs:** Characterized using assumptions provided above or evaluated assumptions if available.
- **Year 2 and 3 installs:** Characterized using delta watts assumption and hours of use from the Install Year i.e. the actual deemed (or evaluated if available) assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

Using the example from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through an upstream program.

\[
\Delta \text{kWh}_{\text{1st year installs}} = \left(\frac{29-6.7}{1000}\right) \times 847 \times 1.06 \times 0.899
\]

= 18.0 kWh

\[
\Delta \text{kWh}_{\text{2nd year installs}} = \left(\frac{29-8}{1000}\right) \times 847 \times 1.06 \times 0.043
\]

= 0.9 kWh

**HEATING PENALTY**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[
\Delta \text{kWh}_{\text{Heating penalty}} = - \left(\frac{\text{WattsBase} - \text{WattsEE}}{1000}\right) \times \text{ISR} \times \text{Hours} \times \text{HF} / \eta_{\text{Heat}}
\]

Where:

- HF = Heating Factor or percentage of light savings that must be heated
- = 49%\(^{886}\) for interior or unknown location
- = 0% for exterior or unheated location

\(^{885}\) Negative value because this is an increase in heating consumption due to the efficient lighting.

\(^{886}\) This means that heating loads increase by 49% of the lighting savings. This is based on the average result from REMRate modeling of several different configurations and IL locations of homes.
η\text{Heat} = \text{Efficiency in COP of Heating equipment}

= \text{actual. If not available use}^{887}:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>(COP Heat (COP Estimate)) = (HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1.00</td>
</tr>
<tr>
<td>Unknown^{888}</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

Using the same 8 W LED that is installed in home with 2.0 COP Heat Pump (including duct loss):

\[\Delta k\text{Wh}_{1\text{st year}} = -\frac{0.899 \times 759 \times 0.49}{2.0} \approx -3.7 \text{ kWh}\]

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year. The appropriate baseline shift adjustment should then be applied to all installs.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[\Delta kW = \frac{((\text{WattsBase} - \text{WattsEE}) \times 1000) \times \text{ISR} \times \text{WHFd} \times \text{CF}}{1000}\]

Where:

- WHFd = \text{Waste heat factor for demand to account for cooling savings from efficient lighting.}

| Bulb Location                                      | WHFd
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location</td>
<td>1.11^{889}</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07^{890}</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- CF = \text{Summer Peak Coincidence Factor for measure.}

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>CF^{891}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior single family or unknown location or Multi family in unit</td>
<td>7.1%</td>
</tr>
</tbody>
</table>

^{887} 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. Note efficiency should include duct losses. Defaults provided assume 15% duct loss for heat pumps.

^{888} Calculation assumes 35% Heat Pump and 65% Resistance, which is based upon data from Energy Information Administration, 2009 Residential Energy Consumption Survey, see “HC6.9 Space Heating in Midwest Region.xls”, using average for East North Central Region. Average efficiency of heat pump is based on assumption that 50% are units from before 2006 and 50% from 2006-2014. Program or evaluation data should be used to improve this assumption if available.

^{889} The value is estimated at 1.11 (calculated as 1 + (0.66 * 0.466 / 2.8)). See footnote relating to WHFe for details. Note the 46.6% factor represents the average Residential cooling coincidence factor calculated by dividing average load during the peak hours divided by the maximum cooling load.

^{890} As above but using estimate of 45% of multi family buildings in Illinois having central cooling (based on data from “Table HC7.1 Air Conditioning in U.S. Homes, By Housing Unit Type, 2009” which is for the whole of the US, scaled to IL air conditioning prevalence corrected to US average)

^{891} Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.
### Natural Gas Savings

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

\[
\Delta \text{Therms} = - \left( \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412 \div \eta_{\text{Heat}}
\]

Where:

- **HF** = Heating factor, or percentage of lighting savings that must be replaced by heating system.
  - 49% 892 for interior or unknown location
  - 0% for exterior location

- **0.03412** = Converts kWh to Therms

- **\( \eta_{\text{Heat}} \)** = Average heating system efficiency.
  - 0.70 893

### Water Impact Descriptions and Calculation

N/A

### Deemed O&M Cost Adjustment Calculation

Bulb replacement costs assumed in the O&M calculations are provided below 894.

<table>
<thead>
<tr>
<th>Year</th>
<th>Std Inc.</th>
<th>EISA Compliant Halogen</th>
<th>CFL</th>
<th>LED-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>$0.43</td>
<td>$1.25</td>
<td>N/A</td>
<td>$3.21</td>
</tr>
</tbody>
</table>

892 Average result from REMRate modeling of several different configurations and IL locations of homes

893 This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey). In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

\[(0.24 \times 0.92) + (0.76 \times 0.8) \times (1-0.15) = 0.70\]

894 Baseline and LED lamp costs are based on field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.
In order to account for the shift in baseline due to the Energy Independence and Security Act of 2007, an equivalent annual levelized baseline replacement cost over the lifetime of the LED bulb is calculated. The key assumptions used in this calculation are documented below:

<table>
<thead>
<tr>
<th>Installation Location</th>
<th>Omnidirectional LED Measure Hours</th>
<th>Hours of Use per year 895</th>
<th>Measure Life in Years (capped at 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential and in-unit Multi Family</td>
<td>15,000</td>
<td>759</td>
<td>10</td>
</tr>
<tr>
<td>Exterior</td>
<td>15,000</td>
<td>2475</td>
<td>6.1</td>
</tr>
<tr>
<td>Unknown</td>
<td>15,000</td>
<td>847</td>
<td>10</td>
</tr>
</tbody>
</table>

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below896. It is important to note that for cost-effectiveness screening purposes, the O&M cost adjustments should only be applied in cases where the light bulbs are actually in service and so should be multiplied by the appropriate ISR:

<table>
<thead>
<tr>
<th>Location</th>
<th>Lumen Level</th>
<th>NPV of replacement costs for period</th>
<th>Levelized annual replacement cost savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential and in-unit Multi Family</td>
<td>Lumens &lt;310 or &gt;2600 (non-EISA compliant)</td>
<td>$2.86</td>
<td>$2.86</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$3.14</td>
<td>$2.38</td>
</tr>
<tr>
<td>Exterior</td>
<td>Lumens &lt;310 or &gt;2600 (non-EISA compliant)</td>
<td>$5.96</td>
<td>$5.96</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$9.79</td>
<td>$7.34</td>
</tr>
<tr>
<td>Unknown</td>
<td>Lumens &lt;310 or &gt;2600 (non-EISA compliant)</td>
<td>$3.19</td>
<td>$3.19</td>
</tr>
<tr>
<td></td>
<td>Lumens ≥ 310 and ≤ 2600 (EISA compliant)</td>
<td>$3.50</td>
<td>$2.66</td>
</tr>
</tbody>
</table>

Note incandescent lamps in lumen range <310 and >2600 are exempt from EISA. For halogen bulbs, we assume the same replacement cycle as incandescent bulbs.897 The replacement cycle is based on the location of the lamp and varies based on the hours of use for that location. Both incandescent and halogen lamps are assumed to last for 1,000 hours before needing replacement.

895 Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluations.
896 See “LED TRM Examples_012017.xls” for calculation.
897 The manufacturers of the new minimally compliant EISA Halogens are using regular incandescent lamps with halogen fill gas rather than halogen infrared to meet the standard and so the component rated life is equal to the standard incandescent.
MEASURE CODE: RS-LTG-LEDA-V05-180101

REVIEW DEADLINE: 1/1/2020
5.6 Shell End Use

5.6.1 Air Sealing

**DESCRIPTION**

Thermal shell air leaks are sealed through strategic use and location of air-tight materials. Leaks are detected and leakage rates measured with the assistance of a blower-door. The algorithm for this measure can be used when the program implementation does not allow for more detailed forecasting through the use of residential modeling software.

Prescriptive savings are provided for use only where a blower door test is not possible (for example in large multi family buildings).

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

Air sealing materials and diagnostic testing should meet all eligibility program qualification criteria. The initial and final tested leakage rates should be performed in such a manner that the identified reductions can be properly discerned, particularly in situations wherein multiple building envelope measures may be implemented simultaneously.

**DEFINITION OF BASELINE EQUIPMENT**

The existing air leakage should be determined through approved and appropriate test methods using a blower door. The baseline condition of a building upon first inspection significantly impacts the opportunity for cost-effective energy savings through air-sealing.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 15 years.\(^{898}\)

**DEEMED MEASURE COST**

The actual capital cost for this measure should be used in screening.

**LOADSHAPE**

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat
Loadshape R10 - Residential Electric Heating and Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
\text{CF}_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)}
\]

---

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Methodology 1: Blower Door Test

Preferred methodology unless blower door testing is not possible.

\[ \Delta kWh = \Delta kWh_{\text{cooling}} + \Delta kWh_{\text{heating}} \]

Where:

- \( \Delta kWh_{\text{cooling}} \) = If central cooling, reduction in annual cooling requirement due to air sealing
- \( \Delta kWh_{\text{heating}} \) = If central heating, reduction in annual heating requirement due to air sealing
- \( CFM50_{\text{existing}} \) = Infiltration at 50 Pascals as measured by blower door before air sealing.
- \( CFM50_{\text{new}} \) = Infiltration at 50 Pascals as measured by blower door after air sealing.
- \( N_{\text{cool}} \) = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

### Table: N_cool (by # of stories)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>39.5</td>
<td>35.0</td>
<td>32.1</td>
<td>28.4</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>38.9</td>
<td>34.4</td>
<td>31.6</td>
<td>28.0</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>41.2</td>
<td>36.5</td>
<td>33.4</td>
<td>29.6</td>
</tr>
<tr>
<td>4 (St Louis, MO)</td>
<td>40.4</td>
<td>35.8</td>
<td>32.9</td>
<td>29.1</td>
</tr>
<tr>
<td>5 (Paducah, KY)</td>
<td>43.6</td>
<td>38.6</td>
<td>34.5</td>
<td>31.3</td>
</tr>
</tbody>
</table>
60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location[^03]:

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>CDD 65</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>820</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>842</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,108</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,570</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,370</td>
</tr>
</tbody>
</table>

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75[^04]

0.018 = Specific Heat Capacity of Air (Btu/ft³°F)

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following[^05]:

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>SEER Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>2006 - 2014</td>
<td>13</td>
</tr>
<tr>
<td>Central AC After 1/1/2015</td>
<td>13</td>
</tr>
<tr>
<td>Heat Pump After 1/1/2015</td>
<td>14</td>
</tr>
</tbody>
</table>

LM = Latent multiplier to account for latent cooling demand[^06]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>3.3</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>3.2</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>3.7</td>
</tr>
<tr>
<td>4 (St Louis, MO)</td>
<td>3.6</td>
</tr>
<tr>
<td>5 (Paducah, KY)</td>
<td>3.7</td>
</tr>
</tbody>
</table>

ΔkWh_heating = If electric heat (resistance or heat pump), reduction in annual electric heating due to

[^03]: National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

[^04]: This factor's source is: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

[^05]: These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

[^06]: Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.
Air Sealing

\[ \text{air sealing} = \frac{((\text{CFM50\_existing} - \text{CFM50\_new})/\text{N\_heat}) \times 60 \times 24 \times \text{HDD} \times 0.018}{\eta\text{Heat} \times 3,412} \]

\( \text{N\_heat} \) = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

\( \text{N\_heat} \) = Based on climate zone, building height and exposure level.

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>N_heat (by # of stories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>23.8, 21.1, 19.3, 17.1</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>23.9, 21.1, 19.4, 17.2</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>24.2, 21.5, 19.7, 17.4</td>
</tr>
<tr>
<td>4 (St Louis, MO)</td>
<td>25.4, 22.5, 20.7, 18.3</td>
</tr>
<tr>
<td>5 (Paducah, KY)</td>
<td>27.8, 24.6, 22.6, 20.0</td>
</tr>
</tbody>
</table>

HDD = Heating Degree Days

HDD = Dependent on location.

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>HDD 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>5,352</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>5,113</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>4,379</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>3,378</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>3,438</td>
</tr>
</tbody>
</table>

\( \eta\text{Heat} \) = Efficiency of heating system

\( \eta\text{Heat} \) = Actual. If not available refer to default table below.

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \eta\text{Heat (Effective COP Estimate)} = (\text{HSPF}/3.412)*0.85 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>

3412 = Converts Btu to kWh

---

907 N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model (see LBNL paper 21040, Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings; Sherman, 1986; page v-vi, Appendix page 7-9) to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

908 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F.

909 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.
For example, a 2 story single family home in Chicago with 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), has pre and post blower door test results of 3,400 and 2,250:

\[
\Delta k\text{Wh}_{\text{heating}} = \Delta k\text{Wh}_{\text{cooling}} + \Delta k\text{Wh}_{\text{heating}} \\
= \left[\frac{(3,400 - 2,250)}{31.6}\right] * 60 * 24 * 842 * 0.75 * 0.018 / (1000 * 10.5) + \left[\frac{(3,400 - 2,250)}{19.4}\right] * 60 * 24 * 5113 * 0.018 / (1.92 * 3,412) \\
= 182 + 1199 \\
= 1,381 \text{ kWh}
\]

\[
\Delta k\text{Wh}_{\text{heating}} = \text{If gas furnace heat, kWh savings for reduction in fan run time} \\
= \Delta \text{Therms} * F_e * 29.3 \\
F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption} \\
= 3.14% \quad ^9_{10} \\
29.3 = \text{kWh per therm}
\]

For example, a well shielded, 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, has pre and post blower door test results of 3,400 and 2,250 (see therm calculation in Natural Gas Savings section):

\[
\Delta k\text{Wh} = 109.1 * 0.0314 * 29.3 \\
= 100 \text{ kWh}
\]

**Methodology 2: Prescriptive Infiltration Reduction Measures**

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible. Cooling savings are not quantified using Methodology 2.

\[
\Delta k\text{Wh}_{\text{heating}} = (\Delta k\text{Wh}_{\text{gasket}} + \Delta k\text{Wh}_{\text{sweep}} + \Delta k\text{Wh}_{\text{sealing}} + \Delta k\text{Wh}_{\text{WX}}) \times ADJ_{R\times Airsealing}
\]

Where:

\[
\Delta k\text{Wh}_{\text{gasket}} = \text{Annual kWh savings from installation of air sealing gasket on an electric outlet}
\]

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>ΔkWh&lt;sub&gt;gasket&lt;/sub&gt; / gasket</th>
<th>Electric Resistance</th>
<th>Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>10.5</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>10.2</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>8.8</td>
<td>4.4</td>
<td></td>
</tr>
</tbody>
</table>

\(^9_{10}\) F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% \(F_e\). See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

Climate Zone (City based upon) | $\Delta kWh_{\text{gasket}} / \text{gasket}$ | $\Delta kWh_{\text{sweep}} / \text{sweep}$ | $\Delta kWh_{\text{sealing}} / \text{ft}$ | $\Delta kWh_{\text{WX}} / \text{ft}$
--- | --- | --- | --- | ---
4 (Belleville) | 7.0 | 3.5 | 5.8 | 5.6
5 (Marion) | 7.2 | 3.6 | 5.8 | 5.6

$n_{\text{gasket}}$ = Number of gaskets installed

$\Delta kWh_{\text{sweep}}$ = Annual kWh savings from installation of door sweep

Climate Zone (City based upon) | $\Delta kWh_{\text{sweep}} / \text{sweep}$ | $\Delta kWh_{\text{sealing}} / \text{ft}$ | $\Delta kWh_{\text{WX}} / \text{ft}$
--- | --- | --- | ---
1 (Rockford) | 202.4 | 11.6 | 13.5
2 (Chicago) | 195.3 | 11.2 | 13.0
3 (Springfield) | 169.3 | 9.7 | 11.3
4 (Belleville) | 134.9 | 7.7 | 9.0
5 (Marion) | 137.9 | 7.9 | 9.2

$n_{\text{sweep}}$ = Number of sweeps installed

$\Delta kWh_{\text{sealing}}$ = Annual kWh savings from foot of caulking, sealing, or polyethylene tape

Climate Zone (City based upon) | $\Delta kWh_{\text{sealing}} / \text{ft}$ | $\Delta kWh_{\text{WX}} / \text{ft}$
--- | --- | ---
1 (Rockford) | 11.6 | 13.5
2 (Chicago) | 11.2 | 13.0
3 (Springfield) | 9.7 | 11.3
4 (Belleville) | 7.7 | 9.0
5 (Marion) | 7.9 | 9.2

$lf_{\text{sealing}}$ = linear feet of caulking, sealing, or polyethylene tape

$\Delta kWh_{\text{WX}}$ = Annual kWh savings from window weatherstripping or door weatherstripping

Climate Zone (City based upon) | $\Delta kWh_{\text{WX}} / \text{ft}$
--- | ---
1 (Rockford) | 13.5
2 (Chicago) | 13.0
3 (Springfield) | 11.3
4 (Belleville) | 9.0
5 (Marion) | 9.2

$lf_{\text{WX}}$ = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{\text{Airsealing}}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings.

$= 80\%$

---

Though we do not have a specific evaluation to point to, modeled savings have often been found to overclaim. Further VEIC reviewed these deemed estimates and consider them to likely be a high estimate. As such an 80% adjustment is applied, and this could be further refined with future evaluations.
**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = (\Delta kWh_{cooling} / FLH_{cooling}) \times CF \]

Where:

- \( FLH_{cooling} \) = Full load hours of air conditioning
- \( = \) Dependent on location\(^{913}\):  
  
<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Single Family</th>
<th>Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
</tbody>
</table>

- \( CF_{SSP} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)  
  \( = 68\%^{914} \)

- \( CF_{SSP} \) = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)  
  \( = 72\%^{915} \)

- \( CF_{PJM} \) = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)  
  \( = 46.6\%^{916} \)

Other factors as defined above

For example, a well shielded, 2 story single family home in Chicago with 10.5 SEER central cooling and a heat pump with COP of 2.0, has pre and post blower door test results of 3,400 and 2,250:

\[ \Delta kW_{SSP} = \frac{182}{570} \times 0.68 \]

\[ = 0.22 kW \]

\[ \Delta kW_{PJM} = \frac{182}{570} \times 0.466 \]

\[ = 0.15 kW \]

**NATURAL GAS SAVINGS**

*Methodology 1: Blower Door Test*

Preferred methodology unless blower door testing is not possible.

If Natural Gas heating:

---

\(^{913}\) Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH.

\(^{914}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{915}\) Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

\(^{916}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
\[ \Delta\text{Therms} = \frac{((\text{CFM50}_{\text{existing}} - \text{CFM50}_{\text{new}})/\text{N}_\text{heat}) \times 60 \times 24 \times \text{HDD} \times 0.018}{(\eta_{\text{Heat}} \times 100,000)} \]

Where:

- \(\text{N}_\text{heat}\) = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
  - Based on climate zone and building height\(^{917}\)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>(\text{N}_\text{heat}) (by # of stories)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>23.8 21.1 19.3 17.1</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>23.9 21.1 19.4 17.2</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>24.2 21.5 19.7 17.4</td>
</tr>
<tr>
<td>4 (St Louis, MO)</td>
<td>25.4 22.5 20.7 18.3</td>
</tr>
<tr>
<td>5 (Paducah, KY)</td>
<td>27.8 24.6 22.6 20.0</td>
</tr>
</tbody>
</table>

- \(\text{HDD}\) = Heating Degree Days
  - dependent on location\(^{918}\):

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>HDD 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>5,352</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>5,113</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>4,379</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>3,378</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>3,438</td>
</tr>
</tbody>
</table>

- \(\eta_{\text{Heat}}\) = Efficiency of heating system
  - Equipment efficiency * distribution efficiency
  - Actual\(^{919}\). If not available use 72%\(^{920}\).

Other factors as defined above

For example, a 2 story single family home in Chicago with a gas furnace with system efficiency of 70%, has pre and post blower door test results of 3,400 and 2,250:

\[ \Delta\text{Therms} = \left(\frac{(3,400 - 2,250)/19.4}{0.72 \times 100,000}\right) = 109.1 \text{ therms} \]

\(^{917}\) N-factor is used to convert 50-pascal blower door air flows to natural air flows and is dependent on geographic location and # of stories. These were developed by applying the LBNL infiltration model [see LBNL paper 21040, *Exegesis of Proposed ASHRAE Standard 119: Air Leakage Performance for Detached Single-Family Residential Buildings*; Sherman, 1986; page v-vi, Appendix page 7-9] to the reported wind speeds and outdoor temperatures provided by the NRDC 30 year climate normals. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.


\(^{919}\) 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](http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

\(^{920}\) Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.
Methodology 2: Prescriptive Infiltration Reduction Measures

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible.

\[ \Delta \text{therms} = (\Delta \text{therms}_{\text{gasket}} \cdot n_{\text{gasket}} + \Delta \text{therms}_{\text{sweep}} \cdot n_{\text{sweep}} + \Delta \text{therms}_{\text{sealing}} \cdot l_{\text{sealing}} + \Delta \text{therms}_{\text{WX}} \cdot l_{\text{WX}}) \cdot \text{ADJR}_{\text{Airsealing}} \]

Where:

- \( \Delta \text{therms}_{\text{gasket}} \) = Annual therm savings from installation of air sealing gasket on an electric outlet
- \( n_{\text{gasket}} \) = Number of gaskets installed
- \( \Delta \text{therms}_{\text{sweep}} \) = Annual therm savings from installation of door sweep
- \( n_{\text{sweep}} \) = Number of sweeps installed
- \( \Delta \text{therms}_{\text{sealing}} \) = Annual therm savings from foot of caulking, sealing, or polyethylene tape
- \( l_{\text{sealing}} \) = linear feet of caulking, sealing, or polyethylene tape
- \( \Delta \text{therms}_{\text{WX}} \) = Annual therm savings from window weatherstripping or door weatherstripping
- \( l_{\text{WX}} \) = Linear feet of window weatherstripping or door weatherstripping

### Table 1: \( \Delta \text{therms}_{\text{gasket}} / \text{gasket} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>( \Delta \text{therms}_{\text{gasket}} / \text{gasket} )</th>
<th>Gas Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>0.49</td>
<td></td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>0.33</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2: \( \Delta \text{therms}_{\text{sweep}} / \text{sweep} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>( \Delta \text{therms}_{\text{sweep}} / \text{sweep} )</th>
<th>Gas Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>9.46</td>
<td></td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>9.13</td>
<td></td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>7.92</td>
<td></td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>6.31</td>
<td></td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>6.45</td>
<td></td>
</tr>
</tbody>
</table>

### Table 3: \( \Delta \text{therms}_{\text{sealing}} / \text{ft} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>( \Delta \text{therms}_{\text{sealing}} / \text{ft} )</th>
<th>Gas Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>0.54</td>
<td></td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: \( \Delta \text{therms}_{\text{WX}} / \text{ft} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>( \Delta \text{therms}_{\text{WX}} / \text{ft} )</th>
<th>Gas Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>0.63</td>
<td></td>
</tr>
</tbody>
</table>

---

### Climate Zone (City based upon) vs. Δtherms\(_{ax}\) / ft Gas Heat

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Δtherms(_{ax}) / ft Gas Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 (Chicago)</td>
<td>0.61</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>0.53</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>0.42</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>0.43</td>
</tr>
</tbody>
</table>

\(I_{WX}\) = Linear feet of window weatherstripping or door weatherstripping

\(ADJ_{RxAirsealing}\) = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings.

\(= 80\%\)

### WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

### DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

### MEASURE CODE: RS-SHL-AIRS-V06-180101

### REVIEW DEADLINE: 1/1/2020

---

\(^{922}\) Though we do not have a specific evaluation to point to, modeled savings have often been found to overclaim. Further VEIC reviewed these deemed estimates and consider them to likely be a high estimate. As such an 80% adjustment is applied, and this could be further refined with future evaluations.
5.6.2 Basement Sidewall Insulation

DESCRIPTION

Insulation is added to a basement or crawl space. Insulation added above ground in conditioned space is modeled the same as wall insulation. Below ground insulation is adjusted with an approximation of the thermal resistance of the ground. Insulation in unconditioned spaces is modeled by reducing the degree days to reflect the smaller but non-zero contribution to heating and cooling load. Cooling savings only consider above grade insulation, as below grade has little temperature difference during the cooling season.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

DEFINITION OF EFFICIENT EQUIPMENT

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

DEFINITION OF BASELINE EQUIPMENT

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no basement wall or ceiling insulation.

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 25 years.\(^{923}\)

DEEMED MEASURE COST

The actual installed cost for this measure should be used in screening.

DEEMED O&M COST ADJUSTMENTS

N/A

LOADSHAPE

- Loadshape R08 - Residential Cooling
- Loadshape R09 - Residential Electric Space Heat
- Loadshape R10 - Residential Electric Heating and Cooling

COINCIDENCE FACTOR

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \]

\[ = 68\%^{924} \]


\(^{924}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
\textbf{Algorithm}

\textbf{CALCULATION OF SAVINGS}

\textbf{ELECTRIC ENERGY SAVINGS}

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

\[ \Delta \text{kWh} = (\Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}}) \]

Where:

- \( \Delta \text{kWh}_{\text{cooling}} \) = If central cooling, reduction in annual cooling requirement due to insulation
  \[ = \left( \frac{((1/R_{\text{old AG}} - 1/(R_{\text{added}} + R_{\text{old AG}})) \times L_{\text{basement wall total}} \times H_{\text{basement wall AG}} \times (1 - \text{Framing factor})) \times 24 \times \text{CDD} \times \text{DUA}}{(1000 \times \eta_{\text{Cool}})} \right) \times \text{ADJ}_{\text{Basement Cool}} \]

- \( R_{\text{added}} \) = R-value of additional spray foam, rigid foam, or cavity insulation.
- \( R_{\text{old AG}} \) = R-value value of foundation wall above grade.
  \[ = \text{Actual, if unknown assume } 1.0^{927} \]
- \( L_{\text{basement wall total}} \) = Length of basement wall around the entire insulated perimeter (ft)
- \( H_{\text{basement wall AG}} \) = Height of insulated basement wall above grade (ft)
- \( \text{Framing factor} \) = Adjustment to account for area of framing when cavity insulation is used
  \[ = 0\% \text{ if Spray Foam or External Rigid Foam} \]
  \[ = 25\% \text{ if studs and cavity insulation}^{928} \]
- \( 24 \) = Converts hours to days
- \( \text{CDD} \) = Cooling Degree Days
  \[ = \text{Dependent on location and whether basement is conditioned}^{929} \]

\[^{925}\text{Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’}.\]

\[^{926}\text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.}\]


\[^{928}\text{ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1}\]

\[^{929}\text{National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.}\]
### 5.6.2 Basement Sidewall Insulation

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Conditioned CDD 65</th>
<th>Unconditioned CDD 65&lt;sup&gt;930&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>820</td>
<td>263</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>842</td>
<td>281</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>1,108</td>
<td>436</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,570</td>
<td>538</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,370</td>
<td>570</td>
</tr>
<tr>
<td>Weighted Average&lt;sup&gt;931&lt;/sup&gt;</td>
<td>947</td>
<td>325</td>
</tr>
</tbody>
</table>

**DUA** = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75<sup>932</sup>

**1000** = Converts Btu to kBtu

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

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:<sup>933</sup>

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>ηCool Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>2006 - 2014</td>
<td>13</td>
</tr>
<tr>
<td>Central AC After 1/1/2015</td>
<td>13</td>
</tr>
<tr>
<td>Heat Pump After 1/1/2015</td>
<td>14</td>
</tr>
</tbody>
</table>

**ADJ<sub>BasementCool</sub>** = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings<sup>934</sup>.

= 80%

**ΔkWh<sub>heating</sub>** = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

\[
= \left(\frac{\left(1/R_{\text{old\_BG}} - 1/(R_{\text{added}}+R_{\text{old\_BG}})\right)}{(\text{L}_{\text{basement\_wall\_total}} \times \text{H}_{\text{basement\_wall\_AG}} \times (1-\text{Framing\_factor}) + (\text{L}_{\text{basement\_wall\_total}} \times (\text{H}_{\text{basement\_wall\_total}} - \text{H}_{\text{basement\_wall\_AG}}) \times (1-\text{Framing\_factor}))]}{24 \times \text{HDD}} \right) \times \left(\frac{1}{\eta_{\text{Heat}}}\right) \times \text{ADJ}_{\text{BasementHeat}}
\]

Where

\( R_{\text{old\_BG}} \) = R-value value of foundation wall below grade (including thermal resistance of

<sup>930</sup> Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.

<sup>931</sup> Weighted based on number of occupied residential housing units in each zone.

<sup>932</sup> This factor’s source is: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

<sup>933</sup> These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

<sup>934</sup> As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 80%.
the earth)\textsuperscript{935} \\
= dependent on depth of foundation \((H_{\text{basement\_wall\_total}} - H_{\text{basement\_wall\_AG}})\):

= Actual R-value of wall plus average earth R-value by depth in table below

<table>
<thead>
<tr>
<th>Below Grade R-value</th>
<th>Depth below grade (ft)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth R-value ((^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h} / \text{Btu}))</td>
<td>2.44</td>
<td>4.50</td>
<td>6.30</td>
<td>8.40</td>
<td>10.44</td>
<td>12.66</td>
<td>14.49</td>
<td>17.00</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>Average Earth R-value ((^\circ\text{F} \cdot \text{ft}^2 \cdot \text{h} / \text{Btu}))</td>
<td>2.44</td>
<td>3.47</td>
<td>4.41</td>
<td>5.41</td>
<td>6.42</td>
<td>7.46</td>
<td>8.46</td>
<td>9.53</td>
<td>10.69</td>
<td></td>
</tr>
<tr>
<td>Total BG R-value (earth + R-1.0 foundation) default</td>
<td>3.44</td>
<td>4.47</td>
<td>5.41</td>
<td>6.41</td>
<td>7.42</td>
<td>8.46</td>
<td>9.46</td>
<td>10.53</td>
<td>11.69</td>
<td></td>
</tr>
</tbody>
</table>

\(H_{\text{basement\_wall\_total}}\) = Total height of basement wall (ft)

\(HDD\) = Heating Degree Days

= dependent on location and whether basement is conditioned\textsuperscript{936}

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Conditioned HDD 60</th>
<th>Unconditioned HDD 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>5,352</td>
<td>3,322</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>5,113</td>
<td>3,079</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>4,379</td>
<td>2,550</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>3,378</td>
<td>1,789</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>3,438</td>
<td>1,796</td>
</tr>
<tr>
<td>Weighted Average\textsuperscript{937}</td>
<td>4,860</td>
<td>2,895</td>
</tr>
</tbody>
</table>

\(\eta_{\text{Heat}}\) = Efficiency of heating system

= Actual. If not available refer to default table below\textsuperscript{938}

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>(\eta_{\text{Heat}}) (Effective COP Estimate) ((\text{HSPF}/3.413)^*0.85)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>After 2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
</tbody>
</table>

\textsuperscript{935} Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

\textsuperscript{936} National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F for a conditioned basement and 50°F for an unconditioned basement), consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{937} Weighted based on number of occupied residential housing units in each zone.

\textsuperscript{938} These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.
### Basement Sidewall Insulation

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>ηHeat (Effective COP Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>

ADJ_{BasementHeat} = Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings\(^{939}\).

= 60%

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

\[
\Delta kW = (\Delta kW_{cooling} + \Delta kW_{heating})
\]

\[
\Delta kW_{heating} = \text{If gas furnace heat, kWh savings for reduction in fan run time}
\]

\[
\Delta kW_{heating} = \Delta \text{Therms} \times F_e \times 29.3
\]

\[F_e\] = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%\(^{940}\)

29.3 = kWh per therm

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):

\[
\Delta kW = (\Delta kW_{cooling} / FLH_{cooling}) \times CF
\]

Where:

\[
FLH_{cooling} = \text{Full load hours of air conditioning}
\]

\(^{939}\) As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 60%.

\(^{940}\) \(F_e\) is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% \(F_e\). See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.
= dependent on location\(^{941}\):

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Single Family</th>
<th>Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average(^{942})</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

\(\textbf{CF}_{\text{SSP}}\) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)  
\(\textbf{CF}_{\text{SSP}} = 68\%^{943}\)

\(\textbf{CF}_{\text{SSP}}\) = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)  
\(\textbf{CF}_{\text{SSP}} = 72\%^{944}\)

\(\textbf{CF}_{\text{PJM}}\) = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)  
\(\textbf{CF}_{\text{PJM}} = 46.6\%^{945}\)

For example, a single family home in Chicago with a 20 by 25 by 7 foot unconditioned basement, with 3 feet above grade, insulated with R-13 of interior spray foam, 10.5 SEER Central AC and 2.26 COP Heat Pump:

\[
\Delta W_{\text{SSP}} = \frac{39.4}{570} \times 0.68 = 0.047 \text{ kW}
\]

\[
\Delta W_{\text{PJM}} = \frac{39.4}{570} \times 0.466 = 0.032 \text{ kW}
\]

\textbf{NATURAL GAS SAVINGS}

If Natural Gas heating:

\[
\Delta \text{Therms} = \left[\left(\frac{(1/R_{\text{old AG}} - 1/(R_{\text{added}}+R_{\text{old AG}})) \times L_{\text{basement wall total}} \times H_{\text{basement wall AG}} \times (1-\text{Framing factor}) + (1/(R_{\text{old BG}} - 1/(R_{\text{added}}+R_{\text{old BG}})) \times L_{\text{basement wall total}} \times (H_{\text{basement wall total}} - H_{\text{basement wall AG}}) \times (1-\text{Framing factor}) \times 24 \times \text{HDD}}{(\eta_{\text{Heat}} \times 100,067)}\right) \times \text{ADJ}_{\text{Basement Heat}}\right]
\]

\(\eta_{\text{Heat}}\) = Efficiency of heating system

\(^{941}\) Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”,  
\url{http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd%20EPY2%20Evaluation%20Reports/ComEd_Central_AC_Efficiency_Services_PY2_Evaluation_Report_Final.pdf}, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\(^{942}\) Weighted based on number of occupied residential housing units in each zone.

\(^{943}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{944}\) Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

\(^{945}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
= Equipment efficiency * distribution efficiency
= Actual. If unknown assume 72%\(^{946}\)

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 by 7 foot R-2.25 basement, with 3 feet above grade, insulated with R-13 of interior spray foam, and a 72% efficient furnace:

\[
\text{Therms} = \frac{((1/2.25 - 1/(13 + 2.25)) \times (20+25+20+25) \times 3 \times (1-0) + (1/8.67 - 1/(13 + 8.67)) \times (20+25+20+25) \times 4 \times (1-0) \times 24 \times 3079)}{0.72 \times 100,067 \times 0.60} = 78.3 \text{ therms}
\]

WATER IMPACT DESCRIPTIONS AND CALCULATION

N/A

DEEMED O&M COST ADJUSTMENT CALCULATION

N/A

MEASURE CODE: RS-SHL-BINS-V08-180101

REVIEW DEADLINE: 1/1/2020

\(^{946}\) Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.
5.6.3 Floor Insulation Above Crawlspace

**DESCRIPTION**

Insulation is added to the floor above a vented crawl space that does not contain pipes or HVAC equipment. If there are pipes, HVAC, or a basement, it is desirable to keep them within the conditioned space by insulating the crawl space walls and ground. Insulating the floor separates the conditioned space above from the space below the floor, and is only acceptable when there is nothing underneath that could freeze or would operate less efficiently in an environment resembling the outdoors. Even in the case of an empty, unvented crawl space, it is still considered best practice to seal and insulate the crawl space perimeter rather than the floor. Not only is there generally less area to insulate this way, but there are also moisture control benefits. There is a “Basement Insulation” measure for perimeter sealing and insulation. This measure assumes the insulation is installed above an unvented crawl space and should not be used in other situations.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

**DEFINITION OF BASELINE EQUIPMENT**

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be no insulation on any surface surrounding a crawl space.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 25 years.\(^{947}\)

**DEEMED MEASURE COST**

The actual installed cost for this measure should be used in screening.

**DEEMED O&M COST ADJUSTMENTS**

N/A

**LOADSHAPE**

- Loadshape R08 - Residential Cooling
- Loadshape R09 - Residential Electric Space Heat
- Loadshape R10 - Residential Electric Heating and Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

Algorithm

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

\[
\Delta kWh = (\Delta kWh_{cooling} + \Delta kWh_{heating})
\]

Where:

\[
\Delta kWh_{cooling} = \text{If central cooling, reduction in annual cooling requirement due to insulation}
\]

\[
= (((R_{old}^{-1} - 1/(R_{added}+R_{old}^{-1}))) \times \text{Area} \times (1 - \text{Framing_factor})) \times 24 \times \text{CDD} \times \text{DUA} \times \text{ADJ}_{FloorCool}
\]

\[
R_{old} = \text{R-value value of floor before insulation, assuming 3/4” plywood subfloor and carpet with pad}
\]

\[
= \text{Actual. If unknown assume 3.96}
\]

\[
R_{added} = \text{R-value of additional spray foam, rigid foam, or cavity insulation.}
\]

\[
\text{Area} = \text{Total floor area to be insulated}
\]

\[
\text{Framing_factor} = \text{Adjustment to account for area of framing}
\]

\[
= 12 \%
\]

\[
24 = \text{Converts hours to days}
\]

\[
\text{CDD} = \text{Cooling Degree Days}
\]

---

948 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
949 Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.
950 Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
951 Based on 2005 ASHRAE Handbook – Fundamentals: assuming 2x8 joists, 16” OC, ¾” subfloor, ½” carpet with rubber pad, and accounting for a still air film above and below: 1/ [(0.85 cavity share of area / (0.68 + 0.94 + 1.23 + 0.68)) + (0.15 framing share / (0.68 + 7.5” * 1.25 R/in + 0.94 + 1.23 + 0.68))] = 3.96
952 ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1
Climate Zone (City based upon) | Unconditioned CDD<sup>953</sup>  
--- | ---  
1 (Rockford) | 263  
2 (Chicago) | 281  
3 (Springfield) | 436  
4 (Belleville) | 538  
5 (Marion) | 570  
Weighted Average<sup>954</sup> | 325  

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75<sup>955</sup>  
1000 = Converts Btu to kBtu  
ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)  
= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:<sup>956</sup>  

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>ηCool Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>2006 - 2014</td>
<td>13</td>
</tr>
<tr>
<td>Central AC After 1/1/2015</td>
<td>13</td>
</tr>
<tr>
<td>Heat Pump After 1/1/2015</td>
<td>14</td>
</tr>
</tbody>
</table>

ADJ<sub>FloorCool</sub> = Adjustment for cooling savings from floor to account for prescriptive engineering algorithms overclaiming savings<sup>957</sup>.  
= 80%  

ΔkWh<sub>heating</sub> = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= (((1/R<sub>old</sub> - 1/(R<sub>added</sub> + R<sub>old</sub>)) * Area * (1-Framing_factor) * 24 * HDD)/ (3,412 * ηHeating)) * ADJ<sub>FloorHeat</sub>  

HDD = Heating Degree Days<sup>958</sup>

---

<sup>953</sup> Five year average cooling degree days with 75F base temp from DegreeDays.net were used in this table because the 30 year climate normals from NCDC used elsewhere are not available at base temps above 72F.

<sup>954</sup> Weighted based on number of occupied residential housing units in each zone.

<sup>955</sup> Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

<sup>956</sup> These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

<sup>957</sup> As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 80%.

<sup>958</sup> National Climatic Data Center, Heating Degree Days with a base temp of 50°F to account for lower impact of unconditioned space on heating system. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
### 5.6.3 Floor Insulation Above Crawlspace

#### Climate Zone (City based upon) | Unconditioned HDD
---|---
1 (Rockford) | 3,322
2 (Chicago) | 3,079
3 (Springfield) | 2,550
4 (Belleville) | 1,789
5 (Marion) | 1,796
**Weighted Average** | **2,895**

ηHeat = Efficiency of heating system

= Actual. If not available refer to default table below:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>ηHeat (Effective COP Estimate) *(HSPF/3.413)*0.85</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>

ADJ_FloorHeat = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings.

= 60%

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

\[ \Delta k\text{Wh} = (\Delta k\text{Wh}_\text{cooling} + \Delta k\text{Wh}_\text{heating}) \]

\[ = \left(\frac{((1/3.96 - 1/(30+3.96))*(20*25)*(1-0.12)*24*281*0.75)}{(1000*10.5)} \times 0.8 \right) + \left(\frac{((1/3.96 - 1/(30+3.96))*(20*25)*(1-0.15)*24*3079)}{(3412*1.92)} \times 0.6 \right) \]

\[ = (37.8 + 641.7) \]

\[ = 679.5 \text{kWh} \]

\[ \Delta k\text{Wh}_\text{heating} = \text{If gas furnace heat, kWh savings for reduction in fan run time} \]

\[ = \Delta \text{Therms} \times F_e \times 29.3 \]

\[ F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption} \]

---

959 Weighted based on number of occupied residential housing units in each zone.

960 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

961 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 60%.
= 3.14%\textsuperscript{962}
29.3 kWh per therm

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 70% efficient furnace (for therm calculation see Natural Gas Savings section):

\[ \Delta \text{kWh} = 60.4 \times 0.0314 \times 29.3 \]
\[ = 55.6 \text{kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta \text{kW} = (\Delta \text{kWh}_{\text{cooling}} / \text{FLH}_{\text{cooling}}) \times \text{CF} \]

Where:

- \( \text{FLH}_{\text{cooling}} \) = Full load hours of air conditioning
- \( \text{Dependent on location}:\textsuperscript{963} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Single Family</th>
<th>Multifamily</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average\textsuperscript{964}</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

\( \text{CFSSP} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
\[ = 68\%\textsuperscript{965} \]

\( \text{CFSSP} \) = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)
\[ = 72\%\textsuperscript{966} \]

\( \text{CFPJM} \) = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

\textsuperscript{962} F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% \( F_e \). See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

\textsuperscript{963} Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, p.33. An average FLH/Cooling Degree Day (from NCDC) ratio was calculated for these locations and applied to the CDD of the other locations in order to estimate FLH. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\textsuperscript{964} Weighted based on number of occupied residential housing units in each zone.

\textsuperscript{965} Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\textsuperscript{966} Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.
For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, a 10.5 SEER Central AC and a newer heat pump:

\[
\Delta kW_{SSP} = \frac{37.8}{570} \times 0.68 = 0.045 \text{ kW}
\]

\[
\Delta kW_{SSP} = \frac{37.8}{570} \times 0.466 = 0.031 \text{ kW}
\]

**NATURAL GAS SAVINGS**

If Natural Gas heating:

\[
\Delta \text{Therms} = \frac{(1/R_{\text{old}} - 1/(R_{\text{added}}+R_{\text{old}})) \times \text{Area} \times (1-\text{Framing\_factor}) \times 24 \times \text{HDD}}{(100,000 \times \eta_{\text{Heat}}) \times \text{ADJ}_{\text{Floor\_Heat}}}
\]

Where

\[\eta_{\text{Heat}} = \text{Efficiency of heating system}
\]

= Equipment efficiency * distribution efficiency

= Actual. If unknown assume 72%\(^{968}\)

Other factors as defined above

For example, a single family home in Chicago with a 20 by 25 footprint, insulated with R-30 spray foam above the crawlspace, and a 72% efficient furnace:

\[
\Delta \text{Therms} = \frac{(1 / 3.96 - 1 / (30 + 3.96)) \times (20 \times 25) \times (1 - 0.12) \times 24 \times 3079}{(100,000 \times 0.72) \times 0.60} = 60.4 \text{ therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE:** RS-SHL-FINS-V08-180101

**REVIEW DEADLINE:** 1/1/2020

\(^{967}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\(^{968}\) Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.
5.6.4 Wall and Ceiling/Attic Insulation

**DESCRIPTION**

Insulation is added to wall cavities, and/or attic. This measure requires a member of the implementation staff evaluating the pre and post R-values and measure surface areas. The efficiency of the heating and cooling equipment in the home should also be evaluated if possible.

This measure was developed to be applicable to the following program types: RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

This measure requires a member of the implementation staff or a participating contractor to evaluate the pre and post R-values and measure surface areas. The requirements for participation in the program will be defined by the utilities.

**DEFINITION OF BASELINE EQUIPMENT**

The existing condition will be evaluated by implementation staff or a participating contractor and is likely to be empty wall cavities and little or no attic insulation.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 25 years.\(^{969}\)

**DEEMED MEASURE COST**

The actual installed cost for this measure should be used in screening.

**LOADSHAPE**

- Loadshape R08 - Residential Cooling
- Loadshape R09 - Residential Electric Space Heat
- Loadshape R10 - Residential Electric Heating and Cooling

**COINCIDENCE FACTOR**

The summer peak coincidence factor for cooling is provided in two different ways below. The first is used to estimate peak savings during the utility peak hour and is most indicative of actual peak benefits, and the second represents the average savings over the defined summer peak period, and is presented so that savings can be bid into PJM’s Forward Capacity Market.

\[
\begin{align*}
\text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \\
&= 68%^{970} \\
\text{CF}_{\text{SSP}} &= \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \\
&= 72%^{971} \\
\text{CF}_{\text{PJM}} &= \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)}
\end{align*}
\]


\(^{970}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{971}\) Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’. 
Algorithm

**Calculation of Savings**

**Electric Energy Savings**

Where available savings from shell insulation measures should be determined through a custom analysis. When that is not feasible for the program the following engineering algorithms can be used with the inclusion of an adjustment factor to de-rate the heating savings.

\[ \Delta k\text{Wh} = (\Delta k\text{Wh}_{\text{cooling}} + \Delta k\text{Wh}_{\text{heating}}) \]

Where

- \( \Delta k\text{Wh}_{\text{cooling}} \) = If central cooling, reduction in annual cooling requirement due to insulation
  
  \[ = (((1/R_{\text{old}} - 1/R_{\text{wall}}) \cdot A_{\text{wall}} \cdot (1 - \text{Framing\_factor}\_\text{wall}) + (1/R_{\text{old}} - 1/R_{\text{attic}}) \cdot A_{\text{attic}} \cdot (1 - \text{Framing\_factor}\_\text{attic})) \cdot 24 \cdot \text{CDD} \cdot \text{DUA}) / (1000 \cdot \eta_{\text{Cool}}) \cdot \text{ADJ}_{\text{WallAtticCool}} \]

- \( R_{\text{wall}} \) = R-value of new wall assembly (including all layers between inside air and outside air).
- \( R_{\text{attic}} \) = R-value of new attic assembly (including all layers between inside air and outside air).
- \( R_{\text{old}} \) = R-value value of existing assemble and any existing insulation. (Minimum of R-5 for uninsulated assemblies\(^973\))
- \( A_{\text{wall}} \) = Net area of insulated wall (ft\(^2\))
- \( A_{\text{attic}} \) = Total area of insulated ceiling/attic (ft\(^2\))
- Framing\_factor\_wall = Adjustment to account for area of framing = 25%\(^974\)
- Framing\_factor\_attic = Adjustment to account for area of framing = 7%\(^975\)
- 24 = Converts hours to days
- CDD = Cooling Degree Days
- = dependent on location:\(^976\)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>CDD 65</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>820</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>842</td>
</tr>
</tbody>
</table>

\(^972\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.

\(^973\) An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL’s Building Energy Simulation Test for Existing Homes (BESTEST-EX).

\(^974\) ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1

\(^975\) Ibid.

\(^976\) National Climatic Data Center, Cooling Degree Days are based on a base temp of 65°F. There is a county mapping table Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
### Climate Zone (City based upon) CDD 65

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>CDD 65</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (Springfield)</td>
<td>1,108</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,570</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,370</td>
</tr>
<tr>
<td>Weighted Average&lt;sup&gt;977&lt;/sup&gt;</td>
<td>947</td>
</tr>
</tbody>
</table>

**DUA**

= Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75<sup>978</sup>

**1000**

= Converts Btu to kBtu

**ηCool**

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

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following.<sup>979</sup>

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>ηCool Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 2006</td>
<td>10</td>
</tr>
<tr>
<td>2006 - 2014</td>
<td>13</td>
</tr>
<tr>
<td>Central AC After 1/1/2015</td>
<td>13</td>
</tr>
<tr>
<td>Heat Pump After 1/1/2015</td>
<td>14</td>
</tr>
</tbody>
</table>

**ADJ<sub>WallAtticCool</sub>**

= Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings.<sup>980</sup>

= 80%

**kWh<sub>heating</sub>**

= If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

= (((((1 / R<sub>old</sub> - 1 / R<sub>wall</sub>) * A<sub>wall</sub> * (1 - Framing_factor<sub>wall</sub>) + (1 / R<sub>old</sub> - 1 / R<sub>attic</sub>) * A<sub>attic</sub> * (1 - Framing_factor<sub>attic</sub>) * 24 * HDD) / (ηHeat * 3412)) * ADJ<sub>WallAtticHeat</sub>

**HDD**

= Heating Degree Days

= Dependent on location.<sup>981</sup>

---

<sup>977</sup> Weighted based on number of occupied residential housing units in each zone.

<sup>978</sup> This factor’s source is: Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

<sup>979</sup> These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Central AC was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time mean that using the minimum standard is appropriate.

<sup>980</sup> As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 80%.

<sup>981</sup> National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.
<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>HDD 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>5,352</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>5,113</td>
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<td>3 (Springfield)</td>
<td>4,379</td>
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<td>4 (Belleville)</td>
<td>3,378</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>3,438</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>4,860</td>
</tr>
</tbody>
</table>

η<sub>Heat</sub> = Efficiency of heating system

= Actual. If not available refer to default table below.<sup>983</sup>

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>η&lt;sub&gt;Heat&lt;/sub&gt; (Effective COP Estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
<td>6.8</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>2006 - 2014</td>
<td>7.7</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>

3412 = Converts Btu to kWh

ADJ<sub>WallAtticHeat</sub> = Adjustment for wall and attic insulation to account for prescriptive engineering algorithms overclaiming savings<sup>984</sup>.

= 60%

For example, a single family home in Chicago with 990 ft<sup>2</sup> of R-5 walls insulated to R-11 and 700 ft<sup>2</sup> of R-5 attic insulated to R-38, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

\[
\Delta k\text{Wh} = (\Delta k\text{Wh, cooling} + \Delta k\text{Wh, heating})
\]

\[
= (((1/5 - 1/11) * 990 * (1-0.25)) + ((1/5 - 1/38) * 700 * (1-0.07))) * 842 * 0.75 * 24) / (1000 * 10.5) * 0.8) + (((1/5 - 1/11) * 990 * (1-0.25)) + ((1/5 - 1/38) * 700 * (1-0.07))) * 5113 * 24) / (1.92 * 3412) * 0.6)
\]

\[
= 224 + 2181
\]

\[
= 2405 \text{ kWh}
\]

\[\Delta k\text{Wh, heating} = \text{If gas furnace heat, kWh savings for reduction in fan run time}
= \Delta \text{Therms} * F_e * 29.3\]

\[F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption}\]

---

982 Weighted based on number of occupied residential housing units in each zone.

983 These default system efficiencies are based on the applicable minimum Federal Standards. In 2006 the Federal Standard for Heat Pumps was adjusted. While one would expect the average system efficiency to be higher than this minimum, the likely degradation of efficiencies over time means that using the minimum standard is appropriate. An 85% distribution efficiency is then applied to account for duct losses for heat pumps.

984 As demonstrated in two years of metering evaluation by Opinion Dynamics, see Memo “Results for AIC PY6 HPwES Billing Analysis”, dated February 20, 2015. TAC negotiated adjustment factor is 60%.
For example, a single family home in Chicago with 990 ft² of R-5 walls insulated to R-11 and 700 ft² of R-5 attic insulated to R-38, with a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section):

\[ \Delta \text{kWh} = 216.4 \times 0.0314 \times 29.3 \]
\[ = 199.1 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta \text{kW} = (\Delta \text{kWh} \text{ cooling} / \text{FLH} \text{ cooling}) \times \text{CF} \]

Where:

- \( \text{FLH} \text{ cooling} \) = Full load hours of air conditioning
- \( \text{CF} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

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<tr>
<th>Climate Zone (City based upon)</th>
<th>Single Family</th>
<th>Multifamily</th>
</tr>
</thead>
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<tr>
<td>1 (Rockford)</td>
<td>512</td>
<td>467</td>
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<td>2 (Chicago)</td>
<td>570</td>
<td>506</td>
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<tr>
<td>3 (Springfield)</td>
<td>730</td>
<td>663</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average(^\text{987})</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
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\( \text{CF}_{\text{SSP}} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

\[ \text{CF}_{\text{SSP}} = 68\% \text{\(^\text{988}\)} \]

\( \text{CF}_{\text{SSP}} \) = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

\[ \text{CF}_{\text{SSP}} = 72\% \text{\(^\text{989}\)} \]

\( \text{CF}_{\text{PJM}} \) = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

\[ \text{CF}_{\text{PJM}} = 46.6\% \text{\(^\text{990}\)} \]

\(^{985}\) \( F_e \) is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (EF in MMBtu/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% \( F_e \). See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.

\(^{986}\) Based on Full Load Hours from ENERGY Star with adjustments made in a Navigant Evaluation, other cities were scaled using those results and CDD. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

\(^{987}\) Weighted based on number of occupied residential housing units in each zone.

\(^{988}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{989}\) Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PY5 coincident with AIC’s 2010 system peak; ‘Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PY5)’.

\(^{990}\) Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.
For example, a single family home in Chicago with 990 ft\(^2\) of R-5 walls insulated to R-11 and 700 ft\(^2\) of R-5 attic insulated to R-38, 10.5SEER Central AC and 2.26 COP Heat Pump:
\[
\Delta kW_{SSP} = \frac{224}{570} \times 0.68 \\
= 0.27 \text{ kW}
\]
\[
\Delta kW_{PJM} = \frac{224}{570} \times 0.466 \\
= 0.18 \text{ kW}
\]

**NATURAL GAS SAVINGS**

If Natural Gas heating:
\[
\Delta \text{Therms} = \left(\left(\frac{1}{R_{\text{old}}} - \frac{1}{R_{\text{wall}}}\right) \times A_{\text{wall}} \times (1 - \text{Framing factor}_{\text{wall}}) + \left(\frac{1}{R_{\text{old}}} - \frac{1}{R_{\text{attic}}}\right) \times A_{\text{attic}} \times (1 - \text{Framing factor}_{\text{attic}})\right) \times 24 \times \text{HDD} / \left(\eta_{\text{Heat}} \times 100,067 \text{ Btu/therm} \right) \times \text{ADJ}_{\text{WallAtticHeat}}
\]

Where:
- HDD = Heating Degree Days
- HDD = Dependent on location: 991
- \(\eta_{\text{Heat}}\) = Efficiency of heating system
  - Equipment efficiency \* distribution efficiency
  - Actual 993 if unknown assume 72%. 994
- Other factors as defined above

<table>
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991 National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F, consistent with the findings of Belzer and Cort, Pacific Northwest National Laboratory in “Statistical Analysis of Historical State-Level Residential Energy Consumption Trends,” 2004. There is a county mapping table in Volume 1, Section 3.7 providing the appropriate city to use for each county of Illinois.

992 Weighted based on number of occupied residential housing units in each zone.

993 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](http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf) or by performing duct blaster testing.

994 Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses.
For example, a single family home in Chicago with 990 ft$^2$ of R-5 walls insulated to R-11 and 700 ft$^2$ of R-5 attic insulated to R-38, with a gas furnace with system efficiency of 66%:

$$
\Delta \text{Therms} = (((1/5 - 1/11) \times 990 \times (1 - 0.25)) + ((1/5 - 1/38) \times 700 \times (1 - 0.07))) \times 24 \times 5113 / (0.66 \times 100,067) \times 0.60
$$

= 216.4 therms

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**MEASURE CODE: RS-SHL-AINS-V07-180101**

**REVIEW DEADLINE: 1/1/2020**
5.7  Miscellaneous

5.7.1  High Efficiency Pool Pumps

**DESCRIPTION**

Conventional residential outdoor pool pumps are single speed, often oversized, and run frequently at constant flow regardless of load. Single speed pool pumps require that the motor be sized for the task that requires the highest speed. As such, energy is wasted performing low speed tasks at high speed. Two speed and variable speed pool pumps reduce speed when less flow is required, such as when filtering is needed but not cleaning, and have timers that encourage programming for fewer on-hours. Variable speed pool pumps use advanced motor technologies to achieve efficiency ratings of 90% while the average single speed pump will have efficiency ratings between 30% and 70%. This measure is the characterization of the purchasing and installing of an efficient two speed or variable speed residential pool pump motor in place of a standard single speed motor of equivalent horsepower.

This measure was developed to be applicable to the following program types: TOS, NC, RF.

If applied to other program types, the measure savings should be verified.

**DEFINITION OF EFFICIENT EQUIPMENT**

The high efficiency equipment is an ENERGY STAR two speed or variable speed residential pool pump for in-ground pools.

**DEFINITION OF BASELINE EQUIPMENT**

The baseline equipment is a single speed residential pool pump.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The estimated useful life for a two speed or variable speed pool pump is 10 years.

**DEEMED MEASURE COST**

The incremental cost is estimated as $235 for a two speed motor and $549 for a variable speed motor.

**LOADSHAPE**

Loadshape R15 – Residential Pool Pumps

**COINCIDENCE FACTOR**

The coincidence factor for this measure is assumed to be 0.831.

---


996 The CEE Efficient Residential Swimming Pool Initiative, p18, indicates that the average motor life for pools in use year round is 5-7 years. For pools in use for under a third of a year, you would expect the lifetime to be higher so 10 years is selected as an assumption. This is consistent with DEER, 2014 and the ENERGY STAR Pool Pump Calculator assumptions.

997 ENERGY STAR Pool Pump Calculator.

998 Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.
**Algorithm**

**Calculation of Energy Savings**

**Electric Energy Savings**

\[
\Delta kWh \text{ two speed} = \frac{(((\text{Hrs/Day}_{\text{base}} \times \text{GPM}_{\text{base}} \times 60)/\text{EF}_{\text{base}}) - (((\text{Hrs/Day}_{\text{2spH}} \times \text{GPM}_{\text{2spH}} \times 60)/\text{EF}_{\text{2spH}} + (\text{Hrs/Day}_{\text{2spL}} \times \text{GPM}_{\text{2spL}} \times 60)/\text{EF}_{\text{2spL}})))}{1000} \times \text{Days}
\]

\[
\Delta kWh \text{ variable speed} = \frac{(((\text{Hrs/Day}_{\text{base}} \times \text{GPM}_{\text{base}} \times 60)/\text{EF}_{\text{base}}) - (((\text{Hrs/Day}_{\text{vsH}} \times \text{GPM}_{\text{vsH}} \times 60)/\text{EF}_{\text{vsH}} + (\text{Hrs/Day}_{\text{vsL}} \times \text{GPM}_{\text{vsL}} \times 60)/\text{EF}_{\text{vsL}})))}{1000} \times \text{Days}
\]

Where:

- \( \text{Hrs/Day}_{\text{base}} \) = run hours of single speed pump
  
  \( = 11.4 \)

- \( \text{GPM}_{\text{base}} \) = flow of single speed pump (gal/min)
  
  \( = 64.4 \)

- \( 60 \) = minutes per hour

- \( \text{EF}_{\text{base}} \) = Energy Factor of baseline single speed pump (gal/Wh)
  
  \( = 2.1 \)

- \( \text{Hrs/Day}_{\text{2spH}} \) = run hours of two speed pump at high speed
  
  \( = 2 \)

- \( \text{GPM}_{\text{2spH}} \) = flow of two speed pump at high speed (gal/min)
  
  \( = 56 \)

- \( \text{EF}_{\text{2spH}} \) = Energy Factor of two speed pump at high speed (gal/Wh)
  
  \( = 2.4 \)

- \( \text{Hrs/Day}_{\text{2spL}} \) = run hours of two speed pump at low speed
  
  \( = 15.7 \)

- \( \text{GPM}_{\text{2spL}} \) = flow of two speed pump at low speed (gal/min)
  
  \( = 31 \)

- \( \text{EF}_{\text{2spL}} \) = Energy Factor of two speed pump at low speed (gal/Wh)
  
  \( = 5.4 \)

- \( \text{Hrs/Day}_{\text{vsH}} \) = run hours of variable speed pump at high speed
  
  \( = 2 \)

- \( \text{GPM}_{\text{vsH}} \) = flow of variable speed pump at high speed (gal/min)
  
  \( = 50 \)

- \( \text{EF}_{\text{vsH}} \) = Energy Factor of variable speed pump at high speed (gal/Wh)

---

999 The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.5 turnovers per day in the efficient case.
= 3.8
Hrs/Day_{vl} = run hours of variable speed pump at low speed
= 16
GPM_{vl} = flow of variable speed pump at low speed (gal/min)
= 30.6
EF_{vl} = Energy Factor of variable speed pump at high speed (gal/Wh)
= 7.3
Days = Number of days per year that the swimming pool is operational
= 125^{1000}
\Delta kWh \text{ two speed} = (((11.4 \times 64.4 \times 60)/2.1) - (((2 \times 56 \times 60)/2.4 + ((15.7 \times 31 \times 60)/5.4))))/1000 \times 125
= 1,596.0 kWh
\Delta kWh \text{ variable speed} = (((11.4 \times 64.4 \times 60)/2.1) - (((2 \times 50 \times 60)/3.8 + ((16 \times 30.6 \times 60)/7.3))))/1000 \times 125
= 1,921.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS^{1001}**

\[ \Delta kW \text{ two speed} = ((\text{kWh/day}_{\text{base}}/(\text{Hrs/day}_{\text{base}}) - (\text{kWh/day}_{2\text{sp}})/(\text{Hr/day}_{2\text{sp}})) \times \text{CF} \]
\[ \Delta kW \text{ variable speed} = ((\text{kWh/day}_{\text{base}}/(\text{Hrs/day}_{\text{base}}) - (\text{kWh/day}_{\text{var}})/(\text{Hr/day}_{\text{var}})) \times \text{CF} \]

Where:
\[ \text{kWh/day}_{\text{base}} = \text{daily energy consumption of baseline pump, as defined above} \]
= 20.98
\[ \text{Hrs/day}_{\text{base}} = \text{daily run hours of single speed pump} \]
= 11.4
\[ \text{kWh/day}_{2\text{sp}} = \text{daily energy consumption of two speed pump, as defined above} \]
= 8.21
\[ \text{Hr/day}_{2\text{sp}} = \text{run hours of two speed pump} \]
= 17.7
\[ \text{kWh/day}_{\text{var}} = \text{daily energy consumption of variable speed pump, as defined above} \]
= 5.6
\[ \text{Hr/day}_{\text{var}} = \text{run hours of variable speed pump} \]
= 18

^{1000} \text{ Assumes 50\% of pools operated from Memorial Day through Labor Day (100 days) and 50\% of pools operate for a longer span, typically the 5 month period between May and September (150 days), due to their ability to heat the pool.}

^{1001} \text{ The methodology and all assumptions are sourced from the ENERGY STAR Pool Pump Calculator and assume a nameplate horsepower of 1.5 and a pool size of 22,000 gallons, with 2.0 turnovers per day in the base case and 1.5 turnovers per day in the efficient case.}
\[ \text{CF} = \text{Summer Peak Coincidence Factor for measure} \]
\[ = 0.831^{1002} \]
\[ \Delta k\text{W two speed} = \left( \frac{20.98}{11.4} - \frac{8.21}{17.7} \right) \times 0.831 \]
\[ = 1.144 \text{ kW} \]
\[ \Delta k\text{W variable speed} = \left( \frac{20.98}{11.4} - \frac{5.60}{18} \right) \times 0.831 \]
\[ = 1.271 \text{ kW} \]

**NATURAL GAS SAVINGS**
N/A

**WATER IMPACT DESCRIPTIONS AND CALCULATION**
N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**
N/A

**MEASURE CODE:** RS-MSC-RPLP-V01-180101

**REVIEW DEADLINE:** 1/1/2022

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\(^{1002}\) Based on assumptions of daily load pattern through pool season. Assumption was developed for Efficiency Vermont but is considered a reasonable estimate for Illinois.
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6 Cross-Cutting Measures

6.1 Behavior

6.1.1 Adjustments to Behavior Savings to Account for Persistence

DESCRIPTION

Energy efficiency program administrators are increasingly including behavior programs as part of their portfolios. These programs are characterized by various kinds of outreach, education, and customer engagement designed to motivate increases in conservation and energy management behaviors, and most commonly include participant-specific energy usage information. Savings impacts are evaluated by ex-post billing analysis comparing consumption before and after (or with and without) program intervention, and require M&V methods that include customer-specific energy usage regression analysis and randomized controlled trial (RCT) experimental designs, among others (see Behavioral protocol set forth in the IL-TRM Attachment A: Illinois Statewide Net-to-Gross Methodologies for more information). As such, initial calculation of savings is treated as a custom protocol.

An important issue for many stakeholders is whether energy savings from behavior programs continue over time (i.e., whether they persist beyond the initial program year). Behavior programs have now been delivered for a number of years in many jurisdictions. The weight of evaluation evidence indicates that the energy-saving behaviors influenced through these programs can persist beyond the initial period of program intervention, even without continued program participation. This post-treatment savings persistence has implications for calculations of first-year savings, measure life, and cost-effectiveness testing. Accounting for persistence will yield savings and cost-effectiveness estimates that more accurately reflect the true benefits of these programs. Because annual goals are based on first-year savings, programs should only count savings attributable to first-year spending. The effect of persistence of savings beyond the first year should be included in lifetime savings calculations and cost-effectiveness testing.

The protocol below was developed to outline the adjustments that should be made to account for the persistence of savings beyond the year of program delivery. This protocol is applicable to behavior programs of any type, delivered to residential or C&I customers, that has evaluated evidence of program persistence; however, the persistence values in this version of the protocol are specific to residential home energy reports (HERs)-type programs. This general protocol should be used for any type of behavior program once supportable assumptions for persistence exist as measured by multi-year, rigorous evaluation studies; persistence factors for those behavioral programs may differ from the specific factors provided in this measure for HERs-type programs.

Currently, evaluations calculate a custom value on an annual basis to estimate yearly savings. Evaluators typically use a regression analysis to estimate program effects. These regression analyses provide what is called an average treatment effect on the treated (ATT) estimate of program savings. The ATT approach takes advantage of the presence of a randomly assigned control group for each cohort that received reports in the service territory. These

---

1 The protocol outlined here assumes that adjustments to remove the effects of savings from program lift (participation in other utility programs), including legacy uplift, to account for move-outs and opt-outs, to normalize for effects of weather, and any other appropriate adjustments, have been made as part of the custom calculation of savings – this final savings value is referred to as “Measured Savings” in the calculations below.

2 Long-Run Savings and Cost-Effectiveness of Home Energy Reports Programs, Cadmus, October 2014. Also see additional sources in the REFERENCE TABLE below.

3 Residential HERs-type programs: programs that regularly deliver home energy reports to residential customers through direct mail or email channels using a random control trial (RCT) experimental design. At a minimum, the reports include customer-specific usage information used for a comparison to similar households and individualized energy savings tips.
regressions use various methods to account for household-specific usage patterns. Because of the experimental design, we can assume that the treatment and control groups experienced similar historical, political, economic, and other events that had comparable effects on their energy use. Moreover, because these groups experienced generally similar weather conditions, it is not necessary to measure or include weather in the RCT model specification to calculate initial annual savings related to the program.

However, in the case of comparing and summing savings year over year, exogenous factors, such as weather, are likely to make annual estimates non-equivalent. In particular, weather is likely to play an important role in driving behavioral effects, affecting savings magnitude (e.g., a constant percentage change in consumption will result in more cooling savings during a hotter-than-average summer), as well as savings rate (e.g., the percentage change in consumption is likely to be higher during hotter-than-average summers). As such, for this framework, evaluators will adjust for effects related to weather as part of the custom inputs to this protocol. Each evaluator will choose the most appropriate method for weather normalization. For example, one method would be to provide savings using a model specification that incorporates standard weather year inputs (e.g., HDD and CDD), to be used as the initial input into the calculation of annual savings, as well as inputs for cost effectiveness, as outlined below. This input will approximate average savings for a standard weather year based upon historical data. Adjusting savings to a standard weather year is consistent with how other weather-sensitive TRM measures are specified, and will remove weather risk from performance goals and cost-effectiveness testing.

The protocol will become effective for residential HERs-type programs as of January 1, 2018. All ongoing programs will undergo a “reset” upon institution of this protocol. Regardless of any previous history of behavior program delivery, the program year ending December 31, 2018 will be assumed to be Year 1 for all HERs-type programs underway at that time for the purpose of the incorporation of multiyear measure life/savings persistence into cost-effectiveness calculations and for the application of the adjustments to annual savings as outlined below. Should any additional new programs (referred to as “waves” in the calculations below) be established in 2018 or in subsequent years, their first year will be assumed to be Year 1 for that wave – that is, each wave is tracked separately and savings are calculated separately using the approach outlined here. Waves that existed prior to the program year ending December 31, 2018 will continue to be tracked separately for each wave. All residential HERs-type programs implemented prior to January 1, 2018 will assume a one-year measure life; the assumptions and protocols outlined below will not be applied retrospectively to any utility programs. Updates to persistence factors from future evaluations, once incorporated into the IL-TRM, will be used when available for calculation of annual savings values for applicable program years but will not be applied retrospectively to previous years’ first-year savings calculations. All other types of behavior programs will continue to use a one-year measure life until

---

4 For example, a linear fixed-effects regression (LFER) model includes a household-specific intercept to account for time-invariant, household-level factors affecting energy use, and a post program regression (PPR) model uses energy use lags to account for household-specific usage in the year prior to the program.

5 An analysis to confirm that cross-year effects of weather are material, and therefore should be included as outlined here, is planned.

6 In the future, this approach could be empirically tested by comparing actual savings calculated in future program years against standard weather year results, producing a ‘realization rate’ between planned and actual savings results. Standard weather years could potentially be enhanced to better reflect these differences.

7 We acknowledge that this approach is a proxy for estimating actual savings to allow for prospective calculation of lifetime savings. However, a substantial limitation to this approach is the issue of unobserved behavioral ramp-up that is likely to occur for future waves of participants.

8 It is understood that this approach does not accurately take into account that programs have been in place prior to this date, and the fact that customers at that time will have been receiving reports for variable amounts of time, with varied associated actual savings persistence from these earlier program efforts. The difficulties of trying to “phase in” persistence adjustments to reflect this history have been recognized, and the approach outlined here has been recommended by the Illinois TAC members as a reasonable approximation.
supportable evidence exists for savings persistence, at which time this adjustment protocol can be used with appropriate persistence factors.

**DETERMINATION OF EFFICIENT BEHAVIOR**

Behavior programs focus primarily on reducing electricity and natural gas consumption through behavioral changes; this reduction is generally measured through ex-post billing analysis after program intervention. Specific energy conservation and management behaviors are not usually directly observable. The specific definition of the efficient case is part of the design of behavioral programs and is included as part of the custom saving protocol, which will include any adjustment necessary to remove effects of program-related investments in efficient equipment.

**DETERMINATION OF BASELINE BEHAVIOR**

The ideal baseline for behavior programs is the energy usage without the program intervention. Various types of experimental, quasi-experimental, and/or regression-based EM&V approaches are used to present statistically valid approximations to this without-program baseline. The specific definition of the baseline case is part of the design of behavioral programs and is included as part of the custom saving protocol.

**DEEMED LIFETIME/PERSISTENCE OF SAVINGS**

Evaluations in Illinois have shown that savings from residential HERs-type behavior programs can persist into at least the first and second year following discontinuation of program delivery, though on-going savings levels decay in the second year. For other residential RCT programs evaluated to date, savings have been shown to persist for at least 3 years following program delivery, and industry expectations are that savings likely persist beyond that. We assume here that savings persist at some level for 5 years. On-going savings over those 5 years are not equal, however; it is preferable that actual levels of ongoing savings should be calculated by future year as outlined below (see Application of Persistence for Cost-effectiveness) and used in cost-effectiveness and lifetime savings calculations. For other behavior program types without evaluations that quantify levels of persistence, measure life is assumed = 1 year.

---

9 See the Illinois Behavioral protocol set forth in the IL-TRM Attachment A: IL-NTG Methods for more information concerning randomized control trials and quasi-experimental evaluation methods for non-randomized designs for behavior programs.


11 Long-Run Savings and Cost-Effectiveness of Home Energy Reports Programs, Cadmus, October 2014. Also see additional sources in the REFERENCE TABLE below. Given the limited persistence studies available, we acknowledge that using an average of these studies by fuel type may be the best approximation of persistence rates. However, moving forward, the TAC will incorporate additional study values and develop the most appropriate persistence factors, taking into account participant characteristics, such as the duration of exposure, the frequency of reports, baseline usage, as well as the amount of time that has persisted since receiving their final report, and the shape of the persistence curve.

12 Determined as a reasonable preliminary assumption by Illinois TAC members. This assumption should be updated as additional research is conducted on these types of programs, and additional evaluation should be undertaken to assess the reasonableness of this assumption for Illinois-specific programs.

13 This method of applying calculated values for future year benefits is preferred. Alternatively, an effective measure life can be calculated as Effective Measure Life = Total Discounted Lifetime Savings / First Year Savings.
DEEMED MEASURE COST

It is assumed that most behavior changes in residential settings can be accomplished with homeowner labor only and without investment in new equipment; therefore, without evidence to the contrary, measure costs in such residential programs focused on motivating changes in customer behavior may be defined as $0. Costs for C&I programs may include additional staffing, software purchases, etc. Cost for such programs is therefore program specific and is determined on a custom basis.

LOADSHAPE AND COINCIDENCE FACTOR

While there is evidence from analysis of AMI data that the savings loadshape for residential HERs-type programs mirrors the whole-house electric energy load pattern, there are not yet enough data to develop a behavior-specific loadshape. Indications from several unpublished analyses show that these behavior savings occur in a general pattern most closely approximated by the Residential Electric Heating and Cooling Loadshape (R10) than any other current residential measure loadshape; this is therefore recommended as the most reasonable approximation for use until more-specific data are available. Loadshapes and coincidence factors will need to be determined for other types of behavior programs once sufficient data are in hand.

Algorithm

CALCULATION OF SAVINGS

Throughout these protocols, Year T refers to the current reporting year for which annual savings are being determined.

ELECTRIC ENERGY SAVINGS

The algorithm shown below for this measure was developed to calculate the annual persistence-adjusted electric savings in to be reported in year T after adjustment to account for the proportion of the measured savings for that program year that actually reflects any persistent savings from prior years’ program activities (Years T-1, T-2, T-3, and T-4).

---

14 Future evaluation of costs of behavior change is encouraged to help clarify this assumption. In addition, as noted earlier in this measure characterization, in order to ensure double counting of savings does not occur, the protocol outlined here assumes that adjustments to remove the effects of program lift have been made as part of the custom calculation of savings. In a similar manner, given the savings accounted for by other utility programs are removed from the savings claims and cost-effectiveness for the behavior program, the incremental costs associated with such utility program incentivized measures should also be excluded from the behavior program cost-effectiveness analysis, so as to help ensure double counting of costs does not occur in the utility portfolio cost-effectiveness analysis.


16 Calculation algorithms account for attrition of customers out of the service territory, as well as persistence decay. It has been noted that there may also be a need to adjust for cross-year effects of large differences in weather conditions or economic impacts. Custom savings inputs therefore are adjusted for standard year weather. Further studies are needed to help determine the magnitude of such effects and if this is the appropriate way to account for them.

17 This calculation should be carried out separately for each “wave” of behavior programs, where a wave is defined as a newly launched program. For simplicity, any new wave is assumed to start at the beginning of a program year (Year 1) and may include multiple different treatment types such as usage groups, report frequency, etc. For example, any wave added after 2018, will be considered Year 1 in the year they are launched.
\[ \Delta kWh_{T \text{ Adjusted}} = \Delta kWh_{T \text{ Measured}} - (\Delta kWh_{T-1 \text{ Adjusted}} \cdot RR_{T-1,T} \cdot PFE_1) - (\Delta kWh_{T-2 \text{ Adjusted}} \cdot RR_{T-2,T} \cdot PFE_2) - (\Delta kWh_{T-3 \text{ Adjusted}} \cdot RR_{T-3,T} \cdot PFE_3) - (\Delta kWh_{T-4 \text{ Adjusted}} \cdot RR_{T-4,T} \cdot PFE_4) \]

Where:

\( \Delta kWh_{x \text{ Adjusted}} \) = total program annual savings for year X after adjustments to account for persistence (calculated value)

\( \Delta kWh_{x \text{ Measured}} \) = measured kWh savings: total program savings as determined from custom calculation/billing analysis\(^\text{18}\) of participants in program during year X (input value)

\( RR_{Y,X} \) = Program retention rate in year X from year Y participation

\( = \% \) of program participants in year Y that are still in program in year X (input value: calculated as \# participants still in program in year X / \# participants in year Y)

\( PFE_Z \) = Persistence factor - electric (deemed value)

\( = \% \) savings that persist Z years after savings were initially measured, where Z is a number from 1 - 4

\( = \) use table below to select the appropriate value

**Electric Persistence Factors\(^\text{19}\)**

<table>
<thead>
<tr>
<th>Program Type</th>
<th>Program Year T - record 100% of adjusted savings (( \Delta kWh_{T \text{Adjusted}} ) above)</th>
<th>Percent adjusted savings from Year T activities that persist 1 year after year T</th>
<th>Percent adjusted savings from Year T activities that persist 2 years after year T</th>
<th>Percent adjusted savings from Year T activities that persist 3 years after year T</th>
<th>Percent adjusted savings from Year T activities that persist 4 years after year T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential HERs-type (RCT)</td>
<td>100%</td>
<td>80%</td>
<td>54%</td>
<td>31%</td>
<td>15%</td>
</tr>
</tbody>
</table>

\(^\text{18}\) All appropriate adjustments to remove effects of participation in other utility programs, move-outs, opt-outs, to normalize for effects related to weather, and other adjustments as determined by the program experimental design, are assumed to have been made to result in this value for "measured savings". This value has been adjusted for standard year weather terms.

\(^\text{19}\) See REFERENCE TABLES below for sources.
Example of Adjusted Annual Savings Calculations:

Assume the following information on participation and measured savings for the following program years (all adjustments have been made to remove effects of program lift, weather, etc. within the custom savings calculations). Assume 2018 is the first year of all programs (or is the “reset” year).

<table>
<thead>
<tr>
<th>Reporting Year</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td># Participants (households)</td>
<td>120,000</td>
<td>109,000</td>
<td>103,000</td>
<td>99,000</td>
<td>94,000</td>
<td>90,000</td>
</tr>
<tr>
<td>kWh per participant (household)</td>
<td>200</td>
<td>250</td>
<td>245</td>
<td>250</td>
<td>250</td>
<td>265</td>
</tr>
<tr>
<td>Measured kWh savings (custom)</td>
<td>24,000,000</td>
<td>27,250,000</td>
<td>25,235,000</td>
<td>24,750,000</td>
<td>23,500,000</td>
<td>23,850,000</td>
</tr>
</tbody>
</table>

Calculation of Retention Rates:

For use in 2019:
- RR\(_{2018,2019}\) = 109,000/120,000 = 0.908

For use in 2020:
- RR\(_{2018,2020}\) = 103,000/120,000 = 0.862
- RR\(_{2019,2020}\) = 94,000/109,000 = 0.862
- RR\(_{2020,2020}\) = 99,000/103,000 = 0.913
- RR\(_{2019,2020}\) = 94,000/99,000 = 0.949
- RR\(_{2018,2020}\) = 103,000/109,000 = 0.945
- RR\(_{2021,2020}\) = 94,000/99,000 = 0.949

For use in 2021:
- RR\(_{2018,2021}\) = 99,000/120,000 = 0.825
- RR\(_{2019,2021}\) = 99,000/109,000 = 0.908
- RR\(_{2020,2021}\) = 99,000/103,000 = 0.961
- RR\(_{2019,2021}\) = 99,000/109,000 = 0.862
- RR\(_{2020,2021}\) = 103,000/109,000 = 0.945
- RR\(_{2021,2021}\) = 99,000/99,000 = 0.949

For use in 2022:
- RR\(_{2018,2022}\) = 94,000/120,000 = 0.783
- RR\(_{2019,2022}\) = 94,000/109,000 = 0.862
- RR\(_{2020,2022}\) = 94,000/103,000 = 0.913
- RR\(_{2019,2022}\) = 94,000/99,000 = 0.949
- RR\(_{2020,2022}\) = 94,000/94,000 = 0.978
- RR\(_{2021,2022}\) = 94,000/90,000 = 0.957
- RR\(_{2022,2022}\) = 90,000/94,000 = 0.957

Calculation of Adjusted Annual Savings:

\(\Delta kWh_{2018\text{Adjusted}} = 24,000,000 \text{ kWh}\)

\(\Delta kWh_{2019\text{Adjusted}} = 27,250,000 - (24,000,000 * 0.908 * 0.80)\)

\(\Delta kWh_{2020\text{Adjusted}} = 25,235,000 - (9,816,400 * 0.945 * 0.80) - (24,000,000 * 0.858 * 0.54)\)

\(\Delta kWh_{2021\text{Adjusted}} = 24,750,000 - (6,694,122 * 0.961 * 0.80) - (9,816,400 * 0.908 * 0.54) - (24,000,000 * 0.825 * 0.31)\)

\(\Delta kWh_{2022\text{Adjusted}} = 23,500,000 - (8,652,382 * 0.949 * 0.80) - (6,694,122 * 0.913 * 0.54) - (9,816,400 * 0.862 * 0.31) - (24,000,000 * 0.783 * 0.15)\)

\(\Delta kWh_{2023\text{Adjusted}} = 23,850,000 - (8,188,837 * 0.957 * 0.80) - (8,652,382 * 0.909 * 0.54) - (6,694,122 * 0.874 * 0.31) - (9,816,400 * 0.826 * 0.15)\)

Apply the same approach to calculate adjusted annual kW and Therms.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

Coincident peak demand savings in year T should also be adjusted to account for persistence from previous years using a similar algorithm\(^\text{20}\).

---

\(^{20}\) While there are no current studies that evaluate the persistence of peak savings, without more-specific information on the actual behaviors undertaken by program participants and their corresponding peak savings, it seems reasonable to assume that peak savings will also persist in a similar pattern; both of the approaches given assume persistence in peak savings. Further
If peak demand is measured directly by the custom savings analysis:

\[ kW_{\text{Adjusted}} = \Delta kW_{\text{Measured}} - (\Delta kW_{\text{T-1 Adjusted}} \times RR_{\text{T-1,T}} \times PFE_1) - (\Delta kW_{\text{T-2 Adjusted}} \times RR_{\text{T-2,T}} \times PFE_2) - (\Delta kW_{\text{T-3 Adjusted}} \times RR_{\text{T-3,T}} \times PFE_3) - (\Delta kW_{\text{T-4 Adjusted}} \times RR_{\text{T-4,T}} \times PFE_4) \]

Where:
- \( \Delta kW_x \) \text{ Adjusted} = total program demand savings for year X after adjustments to account for persistence (calculated value)
- \( \Delta kW_x \) \text{ Measured} = total program demand savings as determined from custom calculation / billing analysis\(^{21}\) of participants in program during year X (input value)

Other variables as defined above

If peak demand is not measured directly by the custom savings analysis, peak demand should be calculated as follows:

\[ \Delta kW_{\text{T}} \text{ Adjusted} = (\Delta kWh_{\text{T Adjusted Summer}} / \#\text{summer hours}) \times \text{peak adjustment factor} \]

Where:
- \( \Delta kWh_{\text{T Adjusted Summer}} \) = average adjusted electric energy savings (calculated above) for peak summer months
  - \( = \Delta kWh_{\text{T Adjusted}} \times 0.42 \times (3/5) \)
  - \( = \Delta kWh_{\text{T Adjusted}} \times 0.25 \)
- Where:
  - 0.42 = Summer Loadshape % for May – Sept
  - 3/5 = proportion of May-Sept hours that fall in June, July, and Aug
- \# summer hours = \# hours in June, July, and Aug
  - \( = 8760 / 4 \)
- Where: 8760 = Hours per year
- peak adjustment factor = adjustment for peak k/w over average kW for these hours
  - \( = 1.5^{22} \)

**Natural Gas Energy Savings**

The algorithm shown below for this measure was developed to calculate the annual persistence-adjusted Therm savings in to be reported in year T after adjustment to account for the proportion of the measured savings for that program year that actually reflects any persistent savings from prior years’ program activities (Years T-1, T-2, T-3, evaluation should be undertaken to clarify this point and determine appropriate peak-specific persistence values.

\(^{21}\) All appropriate adjustments to remove effects of participation in other utility programs, move-outs, opt-outs, to normalize for effects related to weather, and other adjustments as determined by the program experimental design, are assumed to have been made to result in this value for “measured savings”. This value has been adjusted for standard year weather terms.

and T-4).\textsuperscript{23}

\[
\Delta \text{Therms}_{x}^{\text{Adjusted}} = \Delta \text{Therms}_{x}^{\text{Measured}} - (\Delta \text{Therms}_{1}^{\text{Adjusted}} \times RR_{1,T} \times \text{PFG}_1) - (\Delta \text{Therms}_{2}^{\text{Adjusted}} \times RR_{2,T} \times \text{PFG}_2) - (\Delta \text{Therms}_{3}^{\text{Adjusted}} \times RR_{3,T} \times \text{PFG}_3) - (\Delta \text{Therms}_{4}^{\text{Adjusted}} \times RR_{4,T} \times \text{PFG}_4)
\]

Where:

\[
\Delta \text{Therms}_{x}^{\text{Adjusted}} = \text{total program annual savings for year } X \text{ after adjustments to account for persistence (calculated value)}
\]

\[
\Delta \text{Therms}_{x}^{\text{Measured}} = \text{total program savings as determined from custom calculation/billing analysis}\textsuperscript{24} \text{ of participants in program during year } X \text{ (input value)}
\]

\[
\text{PFG}_Z = \text{Persistence factor - gas (deemed value)}
\]

\[
= \% \text{ savings that persist } Z \text{ years after savings were initially measured, where } Z \text{ is a number from 1} - 4
\]

\[
= \text{ use table below to select the appropriate value}
\]

Other variables as defined above

**Gas Persistence Factors\textsuperscript{25}\textsuperscript{26}**

<table>
<thead>
<tr>
<th>Program Type</th>
<th>Program Year T - record 100% of calculated savings ((\Delta \text{Therms}^{\text{Adjusted}}) above)</th>
<th>Percent adjusted savings from Year T activities that persist 1 year after Year T</th>
<th>Percent adjusted savings from Year T activities that persist 2 years after Year T</th>
<th>Percent adjusted savings from Year T activities that persist 3 years after Year T</th>
<th>Percent adjusted savings from Year T activities that persist 4 years after Year T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential HERs-type (RCT)</td>
<td>100%</td>
<td>PFG\textsubscript{1}</td>
<td>PFG\textsubscript{2}</td>
<td>PFG\textsubscript{3}</td>
<td>PFG\textsubscript{4}</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45%</td>
<td>20%</td>
<td>9%</td>
<td>4%</td>
</tr>
</tbody>
</table>

**APPLICATION OF PERSISTENCE FOR COST-EFFECTIVENESS**

For determination of cost effectiveness (or lifetime savings) of programs in year T, future years’ savings related to the current year activities should be recorded for this measure as savings for each specific year using the table above\textsuperscript{26}. Because of the potentially confounding effects of differences in weather in future years, the savings inputs used (\(\Delta \text{kWh}^{\text{Adjusted}}, \Delta \text{kW}^{\text{Adjusted}}, \Delta \text{Therms}^{\text{Adjusted}}\)) for these future-year savings calculations have been weather

\textsuperscript{23} This calculation should be carried out separately for each “wave” of behavior programs, where a wave is defined as a newly launched program. For simplicity, any new wave is assumed to start at the beginning of a program year (Year 1) and may include multiple different treatment types such as usage groups, report frequency, etc.

\textsuperscript{24} All appropriate adjustments to remove effects of participation in other utility programs, move-outs, opt-outs, to normalize for effects related to weather, and other adjustments as determined by the program experimental design, are assumed to have been made to result in this value for “measured savings”. This value has been adjusted for standard year weather terms.

\textsuperscript{25} See REFERENCE TABLES below for sources.

\textsuperscript{26} These cost-effectiveness calculations assume a retention rate of 100\% after the first program year. Move-out rates and other attrition factors continue to occur and fluctuate year over year, although customers moving within the service territory would continue to produce savings. To be accurate, the value of this persistence for lifetime cost and cost-effectiveness calculations should adjust for attrition through the application of an additional deemed factor. At this time, we do not have sufficient data for such an adjustment and recommend further evaluation to develop appropriate values.
normalized. This input (to be provided by program evaluators) will approximate average savings for a standard weather year based upon historical data.\(^{27}\)

<table>
<thead>
<tr>
<th>Program Year T - record 100% of adjusted annual savings as calculated above</th>
<th>Percent savings from Year T activities that persist 1 year after year T</th>
<th>Percent savings from Year T activities that persist 2 years after year T</th>
<th>Percent savings from Year T activities that persist 3 years after year T</th>
<th>Percent savings from Year T activities that persist 4 years after year T</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \text{kWh}<em>{\text{TAdjusted}}) (\Delta \text{kW}</em>{\text{TAdjusted}}) (\Delta \text{Therms}_{\text{TAdjusted}})</td>
<td>(\Delta \text{kWh}<em>{\text{TAdjusted}}) (\Delta \text{kW}</em>{\text{TAdjusted}}) (\Delta \text{Therms}_{\text{TAdjusted}}) (\ast \text{PFE}_1)</td>
<td>(\Delta \text{kWh}<em>{\text{TAdjusted}}) (\Delta \text{kW}</em>{\text{TAdjusted}}) (\Delta \text{Therms}_{\text{TAdjusted}}) (\ast \text{PFE}_2)</td>
<td>(\Delta \text{kWh}<em>{\text{TAdjusted}}) (\Delta \text{kW}</em>{\text{TAdjusted}}) (\Delta \text{Therms}_{\text{TAdjusted}}) (\ast \text{PFE}_3)</td>
<td>(\Delta \text{kWh}<em>{\text{TAdjusted}}) (\Delta \text{kW}</em>{\text{TAdjusted}}) (\Delta \text{Therms}_{\text{TAdjusted}}) (\ast \text{PFE}_4)</td>
</tr>
</tbody>
</table>

\(^{27}\) In the future, this approach could be empirically tested by comparing actual savings calculated in future program years against standard weather year results, producing a ‘realization rate’ between planned and actual savings results. Standard weather years could potentially be enhanced to better reflect these differences.
Example of Calculation of Cost-effectiveness Inputs – for Electric Savings:

Assume the same information as was used in the Example of Adjusted Annual Savings Calculations.

<table>
<thead>
<tr>
<th>Reporting Year T</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Savings</td>
<td>24,000,000</td>
<td>9,816,400</td>
<td>4,634,922</td>
<td>5,384,166</td>
<td>4,683,858</td>
<td>11,741,354</td>
</tr>
<tr>
<td>*(previously calculated) = ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
<td>ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
<td>ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
<td>ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
<td>ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
<td>ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
<td>ΔkWh&lt;sub&gt;Adjusted&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

For calculating cost effectiveness in 2018:

Cost-effectiveness benefit of 2018 savings in 2019 = ΔkWh<sub>2018 Adjusted</sub> * PFE<sub>1</sub> = 24,000,000 * 0.80 = 19,200,000 kWh
Cost-effectiveness benefit of 2018 savings in 2020 = ΔkWh<sub>2018 Adjusted</sub> * PFE<sub>2</sub> = 24,000,000 * 0.54 = 12,960,000 kWh
Cost-effectiveness benefit of 2018 savings in 2021 = ΔkWh<sub>2018 Adjusted</sub> * PFE<sub>3</sub> = 24,000,000 * 0.31 = 7,440,000 kWh
Cost-effectiveness benefit of 2018 savings in 2022 = ΔkWh<sub>2018 Adjusted</sub> * PFE<sub>4</sub> = 24,000,000 * 0.15 = 3,600,000 kWh

For calculating cost effectiveness in 2019:

Cost-effectiveness benefit of 2019 savings in 2020 = ΔkWh<sub>2019 Adjusted</sub> * PFE<sub>1</sub> = 9,816,400 * 0.80 = 7,853,120 kWh
Cost-effectiveness benefit of 2019 savings in 2021 = ΔkWh<sub>2019 Adjusted</sub> * PFE<sub>2</sub> = 9,816,400 * 0.54 = 5,300,856 kWh
Cost-effectiveness benefit of 2019 savings in 2022 = ΔkWh<sub>2019 Adjusted</sub> * PFE<sub>3</sub> = 9,816,400 * 0.31 = 3,043,084 kWh
Cost-effectiveness benefit of 2019 savings in 2023 = ΔkWh<sub>2019 Adjusted</sub> * PFE<sub>4</sub> = 9,816,400 * 0.15 = 1,472,460 kWh

For calculating cost effectiveness in 2020:

Cost-effectiveness benefit of 2020 savings in 2021 = ΔkWh<sub>2020 Adjusted</sub> * PFE<sub>1</sub> = 6,694,122 * 0.80 = 5,355,297 kWh
Cost-effectiveness benefit of 2020 savings in 2022 = ΔkWh<sub>2020 Adjusted</sub> * PFE<sub>2</sub> = 6,694,122 * 0.54 = 3,614,826 kWh
Cost-effectiveness benefit of 2020 savings in 2023 = ΔkWh<sub>2020 Adjusted</sub> * PFE<sub>3</sub> = 6,694,122 * 0.31 = 2,075,178 kWh
Cost-effectiveness benefit of 2020 savings in 2024 = ΔkWh<sub>2020 Adjusted</sub> * PFE<sub>4</sub> = 6,694,122 * 0.15 = 1,004,118 kWh

Etc.

Apply the same approach to calculate cost-effectiveness inputs for kW and for Therms.

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

**REFERENCE TABLES**

Persistence studies done to date for HERs-type programs capture effects only through a limited time frame and only for the specific program characteristics of the programs studied. They may not accurately represent conditions in Illinois or those for all Illinois programs. The Illinois TAC has determined that an average annual persistence rate across the studies done to date (Table 1 below) is the best currently available data to approximate persistence for the first year for the general class of residential HERs-type programs. Additional information about the rate of decay in the following years is limited. Most studies done to date that assess decay after more than one year do not specifically evaluate after each individual year and instead just calculate an average annual decay across the years studied. This is true of persistence studies for gas HERs-type programs. For them, this protocol assumes a linear on-going rate of decay for five years based on the average annual persistence in Table 1.
Navigant has recently undertaken an evaluation of the ComEd electric HERs program specifically designed to determine the first and second year persistence rate separately for each individual year. The results, shown in Table 2 below, indicate an average increase in the year-over-year persistence factor from year 1 to year 2 of 15%. This level of non-linear increase in the persistence factor is assumed to hold for the five years of electric savings persistence for HERs-type programs and is used to calculate persistence factors used in this protocol. The average annual persistence rate from Table 1 is used for the first year.

It is recommended that the persistence values and the shape of the decay function used in this protocol continue to be updated as further longer term and Illinois-specific evaluations are undertaken.

### Table 1: Annual Persistence Rate for Residential HERs-type (RCT) Programs: Reference Studies

<table>
<thead>
<tr>
<th>Utility/Location</th>
<th>Frequency of Reports when in program</th>
<th>Number of Months in Program Before Terminated</th>
<th>Number of Post-Treatment Savings Analysis Months</th>
<th>Average Annual savings decay</th>
<th>Persistence (= 100% - decay)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Midwest</td>
<td>Monthly &amp; quarterly</td>
<td>24-25</td>
<td>26</td>
<td>21%</td>
<td>79%</td>
<td>1 Electric</td>
</tr>
<tr>
<td>West Coast</td>
<td>Monthly &amp; quarterly</td>
<td>24</td>
<td>29</td>
<td>18%</td>
<td>82%</td>
<td>1 Electric</td>
</tr>
<tr>
<td>West Coast</td>
<td>Monthly &amp; quarterly</td>
<td>25-28</td>
<td>34</td>
<td>15%</td>
<td>85%</td>
<td>1 Electric</td>
</tr>
<tr>
<td>SMUD</td>
<td>Monthly &amp; quarterly</td>
<td>27</td>
<td>12</td>
<td>32%</td>
<td>68%</td>
<td>1 Electric</td>
</tr>
<tr>
<td>Puget Sound Energy</td>
<td>Monthly &amp; quarterly</td>
<td>24</td>
<td>36</td>
<td>11%</td>
<td>89%</td>
<td>1 Electric</td>
</tr>
<tr>
<td>MASS</td>
<td>Monthly &amp; quarterly</td>
<td>26</td>
<td>15</td>
<td>33%</td>
<td>67%</td>
<td>2 Electric</td>
</tr>
<tr>
<td>Illinois (ComEd): First Year</td>
<td>Bimonthly</td>
<td>16-52</td>
<td>12</td>
<td>10%</td>
<td>90%</td>
<td>3 Electric</td>
</tr>
</tbody>
</table>

**Average Annual Electric Savings Persistence:** 80%

<table>
<thead>
<tr>
<th>Utility/Location</th>
<th>Frequency of Reports when in program</th>
<th>Number of Months in Program Before Terminated</th>
<th>Number of Post-Treatment Savings Analysis Months</th>
<th>Average Annual savings decay</th>
<th>Persistence (= 100% - decay)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>MASS</td>
<td>Monthly &amp; quarterly</td>
<td>15</td>
<td>17</td>
<td>64%</td>
<td>36%</td>
<td>2 Gas</td>
</tr>
<tr>
<td>Illinois (Nicor)</td>
<td>Bimonthly</td>
<td>12</td>
<td>12</td>
<td>46%</td>
<td>54%</td>
<td>4 Gas</td>
</tr>
</tbody>
</table>

**Average Annual Gas Savings Persistence:** 45%

Sources:

### Table 2: Year-over-Year Persistence Factors for ComEd Residential HERs Programs

<table>
<thead>
<tr>
<th>Annual Persistence Factor</th>
<th>Wave 1</th>
<th>Wave 3</th>
<th>Wave 5 Non-AMI</th>
<th>Average</th>
<th>Implied Year-over-Year Persistence</th>
<th>Change in Year-over-Year Persistence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1: 11/2013-10/2014</td>
<td>96%</td>
<td>98%</td>
<td>78%</td>
<td>90%</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td>Year 2: 11/2014-10/2015</td>
<td>85%</td>
<td>83%</td>
<td>40%</td>
<td>69%</td>
<td>77%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Source:
http://ilsagfiles.org/SAG_files/Evaluation_Documents/Draft%20Reports%20for%20Comment/ComEd_EPY7/ComEd_HER_Year_Two_Persistence_and_Decay_Study_2016-07-20_Draft.pdf This evaluation extends the analysis of the ComEd program waves reviewed in the 2016 study [#3 above] to the second year after reports were terminated. The study shows an increased rate of decay in year two, indicating that a linear decay rate assumption may not be accurate, at least for the first two years. This assessment of a non-linear decay rate will be reviewed, and the rate as it extends beyond the first two years, will be revisited when there have been additional studies designed to explicitly assess the shape of the decay curve across several years.
MEASURE CODE: CC-BEH-BEHP-V02-160601

REVIEW DEADLINE: 1/1/2021
Illinois Statewide
for Energy Efficiency Version 6.0

Attachment A

Illinois Statewide Net-to-Gross Methodologies

Effective for Evaluation:
January 1\textsuperscript{st}, 2018

All NTG data collection and analysis activities for the program types covered by this document that start after the effective date, January 1, 2018, shall conform to the NTG methods set forth herein.
Attachment A: Illinois Statewide Net-to-Gross Methodologies

Policy Context for this Information


<table>
<thead>
<tr>
<th>ICC Order Docket No. and Date</th>
<th>Program Administrator</th>
<th>NTG Discussion – Order Pages</th>
<th>ICC Link</th>
</tr>
</thead>
</table>

To provide clarity to the ICC directives, the relevant section on IL-NTG Methods is shown in its entirety from the Nicor Gas Order (Docket No. 13-0549). The Nicor Gas Order provides the most detail on the ICC NTG directive in comparison to the other EE orders. The Nicor language is as follows:

The Commission believes that Staff’s recommendations concerning Commission adoption of consistent statewide net-to-gross methodologies (“IL-NTG Methods”) for use by the evaluators are reasonable and will aid in future evaluation of the energy efficiency programs. To help ensure the independence of the evaluators, to improve efficiency in the evaluation process, and to ensure programs across the state as delivered by the various Program Administrators can be meaningfully and consistently evaluated, the Commission hereby adopts Staff’s recommendation that consistent IL-NTG Methods be established for use in the evaluations of comparable energy efficiency programs offered by different Illinois Program Administrators. The Commission notes that Section 8-104(k) of the Act encourages statewide coordination and consistency between the gas and electric energy efficiency programs and Staff’s proposal would help ensure consistency in the evaluation of program performance. The Commission notes that this directive is not to create entirely “new” NTG methodologies for every energy efficiency program, but rather to assess NTG methodologies and survey instruments that have been used to evaluate energy efficiency programs offered in Illinois, and to compile the most justifiable and well-
vetted methodologies (or potentially combine certain components from the existing approaches to better represent the most justifiable and well-vetted method consistent with best practices) in an attachment to the Updated IL-TRM that would get submitted to the Commission for approval. The Commission notes that the IL-NTG Methods will be flexible and adaptable to multiple program designs and budgets and tailored to appropriately assess the specifics of each of the Program Administrators’ energy efficiency programs, consistent with standard NTG methodologies adopted in other states that were filed in this proceeding. The Commission agrees with Staff that in the interest of efficiency, the current program evaluators should take the lead in compiling and formalizing standard methodologies for NTG in Illinois taking into consideration SAG input. Because the existing Plan 1 evaluators are under contract with the Company for the evaluation of the program year three energy efficiency programs, it is appropriate for these existing evaluators to work on and complete the compilation of the IL-NTG Methods over the next year. The Commission recognizes that each year considerable time may be spent vetting NTG methodologies for each program evaluation separately for each utility under the existing evaluation plan review practices; adoption of IL-NTG Methods would save on these limited evaluation resources by having a common reference document for the evaluators to use in estimating net savings for Illinois.

The Commission hereby directs the Company to require its evaluators to collaborate with the other Illinois evaluators and the SAG to use best efforts to reach consensus on the approaches used in assessing NTG in particular markets for both residential and non-residential energy efficiency programs in a manner consistent with the direction described herein. (Pages 41-42)

(16) Northern Illinois Gas Company shall require its evaluators to collaborate with the other Illinois evaluators and the SAG to reach consensus on the most defensible and well-vetted methodologies for assessing net-to-gross ratios in particular markets for both residential and non-residential energy efficiency programs in a manner consistent with the direction provided herein;

(17) ICC Staff shall file the agreed-upon consensus statewide NTG methodologies with the Commission as an attachment to the Updated IL-TRM, and if consensus is not reached on a certain component of the statewide NTG methodologies, that particular non-consensus component should be submitted in a manner consistent with the approach used for non-consensus IL-TRM Updates; (Page 78)

1.2 Programs Currently Covered in this Document

This document is intended to cover the majority of residential and non-residential programs offered in Illinois. Programs covered as of the writing of this document are listed in tables at the beginning of Section 3: Commercial, Industrial, and Public Sector Protocols and Section 4: Residential and Low Income Sector Protocols. If the design of a given program changes significantly, then it may mean that the NTG protocol listed for that program in this document is no longer appropriate. If that happens, the evaluator should follow the procedures outlined below under Section 1.4: Diverging from the IL-NTG Methods.

This document will be updated over time to incorporate new programs and to reflect recommended changes to existing methodologies. All NTG data collection and analysis activities for the program types covered by this document that start after the effective date, January 1, 2018, shall conform to the NTG methods set forth herein.

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28 Evaluation reports on those programs can be found at [http://www.ilsag.info/evaluation-documents.html](http://www.ilsag.info/evaluation-documents.html).
1.3 Updating the IL-NTG Methods

This attachment is part of the IL-TRM and follows the timeline for updating of the IL-TRM, as specified in the Illinois Energy Efficiency Policy Manual. In general, the following will take place:

- Updates will occur annually.
- Any changes to the IL-NTG Methods document will be circulated to the full SAG, and SAG participants will have a ten business day review process.
- Updates will be discussed within the SAG and completed annually.
- The ICC Staff will then submit a Staff Report (with the consensus Updated IL-TRM attached) to the Commission with a request for expedited review and approval.

1.4 Diverging from the IL-NTG Methods

The NTG methods for the programs outlined in this document are partially binding. The criteria for deviating from the IL-NTG Methods document are set forth below. In all cases, the evaluators (or any interested stakeholder) submits the proposed deviation to the full SAG for a ten business day SAG review and comment period. In the event of an objection by a SAG participant, efforts may be made to see if consensus can be reached on the proposed deviation in a subsequent monthly SAG meeting. In this case, a final opportunity for SAG review and comment to the proposed deviation will be provided following the SAG meeting.

Evaluators may modify the approaches described in this document if the following three conditions have been satisfied:

1. Evaluators must explicate within the annual evaluation research plan (or another document) how specific items in the proposed modified NTG method will diverge from what is written in this document. Evaluators must justify why the divergence is appropriate.
2. Prior to the use of the modified NTG method for a particular program, evaluation teams must be in agreement on the use and execution of the modified NTG method.
3. Any objection from SAG participants regarding the proposed modified NTG method is resolved.

Evaluators may test alternative methods of estimating NTG for a particular program in addition to the NTG methods outlined in this document, if the following three conditions have been satisfied:

1. Evaluators must explicate within the annual evaluation research plan (or other document) the proposed alternative NTG method. Evaluators must explain why the proposed alternative NTG method might be superior to the NTG methods outlined in this document for the particular program. Evaluators must discuss the foundation for expecting that the proposed alternative NTG method is likely to produce meaningful results.
2. Prior to the use of the alternative NTG method for a particular program, evaluation teams must be in agreement on the key details of the approach for implementing the alternative NTG method.
3. Any objection from SAG participants regarding the proposed alternative NTG method gets resolved.

When performing alternative NTG methods for a particular program, the choice of methods may vary across the state. For example, if ComEd’s evaluator chooses to test Methods 1 and 2 for a particular program, Ameren’s and Department of Commerce’s evaluators do not also have to perform Methods 1 and 2 for a similar program.

Several sections of this attachment provide example questions that can be used to collect the data required in the NTG algorithms. Adjustments to refine specific question wording, e.g., to better reflect the design of the evaluated program, do not constitute divergence from the IL-NTG Methods.
1.5 Procedure for Non-Consensus Items

Non-consensus items that arise during the development and updating of the IL-NTG Methods document will be handled in substantially the same way as non-consensus IL-TRM Updates are addressed. The approach to be used is as follows.

- Once the Illinois NTG Working Group\(^{29}\) has progressed as far as they can on the methodology, and it has been found that there is non-consensus on a specific Net-to-Gross Methods topic or procedure, the Illinois NTG Working Group shall submit to the ICC Staff and the SAG’s Technical Advisory Committee (TAC) a Comparison Exhibit of Non-Consensus Net-to-Gross Methods topics/procedures within two weeks after the Illinois NTG Working Group has failed to reach consensus. The TAC will then deliberate on the issue with a goal of reaching consensus.

- If consensus does not emerge in the TAC regarding a particular Net-to-Gross Methods topic or procedure, the Comparison Exhibit of Non-Consensus NTG Methods topics/procedures is then sent to the full SAG for their deliberations and input. The SAG provides a forum where experts on all sides of the contested issue can present their expert opinions in an effort to inform parties of the contested issue and to also facilitate consensus.

- If the full SAG is unable to reach consensus, the non-consensus item will be referred to the ICC for resolution at the time of the IL-TRM Update proceeding. After receipt of the Comparison Exhibit of Non-Consensus Net-to-Gross Methods topics/procedures, the ICC Staff will submit a Staff Report to the Commission to initiate a proceeding separate from the consensus IL-TRM Update proceeding to resolve the non-consensus Net-to-Gross Methods topics/procedures.

\(^{29}\) The Illinois NTG Working Group consists primarily of the subset of Evaluators deliberating on NTG methodologies; however, any interested party may participate in the Illinois NTG Working Group.
2 Attribution in Energy Efficiency Programs in General

One of the most difficult aspects of evaluation, and not just within evaluation of energy efficiency programs, is attributing results to a program. Attribution provides credible evidence that there is a causal link between the program activities and the outcomes achieved by the program. Attribution research estimates the difference between the outcomes and those that would have occurred absent the program (i.e., the counterfactual). Put in research terms, evaluators must reject the null hypothesis of no causality through probabilistic statements (e.g., “strong evidence”; “high probability”). As such, it is important to realize that the concept of the counterfactual cannot be proven with certainty. So even though the NTG ratio is a single value, conceptually it is a probabilistic statement. One of the main academics within evaluation stated that there is a “…total and inevitable absence of certain knowledge [arising] from the methods social scientists use” when assessing the counterfactual. (Shadish, et al., 2002) This statement is not about poor methods, but about the counterfactual itself. Because programs work with people and are usually not a laboratory experiment that can be replicated over and over to find out what actions people would have taken absent an intervention, one would need a time machine to take people back in time and not provide the program. Since time machines do not exist, evaluators have developed methods that approximate the counterfactual to the best of their ability.

2.1 Definitions

For energy efficiency programs, evaluators differentiate between savings at a “gross” and “net” level as described below in the short set of relevant definitions. These definitions are not all encompassing or meant to restrict evaluation in any way, but to provide context before additional detail is provided in later sections. Research to determine attribution occurs to allow for a better understanding of the net level of savings.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumers</td>
<td>Nonparticipant</td>
<td>Any consumer who was eligible but did not participate in the subject efficiency program, in a given program year.</td>
</tr>
<tr>
<td></td>
<td>Participant</td>
<td>A consumer who received a service offered through the subject efficiency program, in a given program year; also called program participant. The term “service” is used in this definition to suggest that the service can be a wide variety of inducements, including financial rebates, technical assistance, product installations, training, energy efficiency information, or other services, items, or conditions. Each evaluation plan should define “participant” as it applies to the specific evaluation.</td>
</tr>
<tr>
<td>Gross Impacts</td>
<td>Gross Impacts</td>
<td>The change in energy consumption and/or demand that results directly from program-related actions taken by participants in an energy efficiency program, regardless of why they participated.</td>
</tr>
</tbody>
</table>

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30 A probabilistic statement is not the same as the confidence and precision information calculated based on sampling theory.

31 However, a small number of program designs do lend themselves to experimental or quasi-experimental designs that allow for regression analysis of net impacts.
<table>
<thead>
<tr>
<th>Concept</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribution</td>
<td>Net Impacts</td>
<td>The change in energy consumption and/or demand that is attributable to a particular energy efficiency program. This change in energy use and/or demand may include, implicitly or explicitly, consideration of factors such as free ridership, participant and nonparticipant spillover, and induced market effects. These factors may be considered in how a baseline is defined (e.g., common practice) and/or in adjustments to gross savings values.</td>
</tr>
<tr>
<td></td>
<td>Net-to-Gross Ratio</td>
<td>A factor representing net program savings divided by gross program savings that is applied to gross program impacts to convert them into net program impacts. The factor itself may be made up of a variety of factors that create differences between gross and net savings, commonly including free riders and spillover. The factor can be estimated and applied separately to either energy or demand savings. Note that the net-to-gross ratio (NTGR) = ((1-Free Ridership) + Participant Spillover + Nonparticipant Spillover).</td>
</tr>
<tr>
<td></td>
<td>Core NTGR</td>
<td>1-Free Ridership</td>
</tr>
<tr>
<td>Attribution</td>
<td>Free Rider</td>
<td>A program participant who would have implemented the program’s measures or practices in the absence of the program. Free riders can be: (1) total, in which the participant’s activity would have completely replicated the program measure; (2) partial, in which the participant’s activity would have partially replicated the program measure; or (3) deferred, in which the participant’s activity would have partially or completely replicated the program measure, but at a future time.</td>
</tr>
<tr>
<td>Spillover</td>
<td>Reductions in energy consumption and/or demand caused by the presence of an energy efficiency program. There can be participant and/or nonparticipant spillover.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Participant spillover (PSO)</td>
<td>The additional energy savings that occur as a result of the program’s influence when a program participant independently installs incremental energy efficiency measures or applies energy-saving practices after having participated in the energy efficiency program. Evaluated savings associated with Program Administrator Training programs will also be considered Participant spillover. There are several general categories of participant spillover:</td>
</tr>
<tr>
<td></td>
<td>Inside spillover (ISO): Occurs when program participants implement additional program-induced energy efficiency measures at the program project site.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Outside spillover (OSO): Occurs when program participants implement program-induced efficiency measures at other sites within the Program Administrator’s service territory at which program project measures were not implemented.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Like spillover: Occurs when program participants implement program-induced efficiency measures of the same type as those implemented through the program. Like spillover can occur at the program project sites (ISO) or at other sites within the Program Administrator’s service territory (OSO).</td>
<td></td>
</tr>
</tbody>
</table>
|                  | Unlike spillover: Occurs when program participants implement...
<table>
<thead>
<tr>
<th>Concept</th>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>program-induced efficiency measures of a different type from those implemented through the program. Unlike spillover can occur at the program project sites (ISO) or at other sites within the Program Administrator’s service territory (OSO). Nonparticipant spillover (NPSO) refers to energy savings that occur when a program nonparticipant installs energy efficiency measures or applies energy savings practices as a result of a program’s influence.</td>
</tr>
<tr>
<td></td>
<td>Market</td>
<td>The commercial activity (e.g., manufacturing, distributing, buying, and selling) associated with products and services that affect energy use.</td>
</tr>
<tr>
<td></td>
<td>Market Effects</td>
<td>A change in the structure of a market or the behavior of participants in a market that is reflective of an increase (or decrease) in the adoption of energy efficient products, services, or practices and is causally related to market interventions (e.g., programs). Examples of market effects include increased levels of awareness of energy-efficient technologies among customers and suppliers, increased availability of energy-efficient technologies through retail channels, reduced prices for energy-efficient models, build-out of energy-efficient model lines, and—the end goal—increased market shares for energy-efficient goods, services, and design practices.</td>
</tr>
<tr>
<td></td>
<td>Markets</td>
<td>An analysis that provides an assessment of how and how well a specific market or market segment is functioning with respect to the definition of well-functioning markets or with respect to other specific policy objectives. A market assessment generally includes a characterization or description of the specific market or market segments, including a description of the types and number of buyers and sellers in the market, the key factors that influence the market, the type and number of transactions that occur on an annual basis, and the extent to which market participants consider energy efficiency an important part of these transactions. This analysis may also include an assessment of whether a market has been sufficiently transformed to justify a reduction or elimination of specific program interventions (or whether continued or even increased intervention is necessary). Market assessment can be blended with strategic planning analysis to produce recommended program designs or budgets. One particular kind of market assessment effort is a baseline study, or the characterization of a market before the commencement of a specific intervention in the market for the purpose of guiding the intervention and/or assessing its effectiveness later.</td>
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2.2 Spillover-Specific Issues

Some issues related to spillover are applicable for both residential and non-residential programs and are discussed in this section.

2.2.1 Measure Costs

In order to facilitate analysis of program Total Resource Cost (TRC), estimates of the total incremental measure cost (IMC) at the program level must be developed. IMC values are available for most IL-TRM measures and can be summed to the program level. However, the IMC values for spillover measures could also be estimated and added to this total. The problem is that IMC values for spillover measures can be difficult to estimate. When the magnitude of the savings justifies the effort to estimate the total IMC for spillover measures, the following approaches should be used.

- In cases where the evaluator believes the spillover measure incremental costs are not materially different from the rebated measure incremental costs, the evaluator may multiply the IMC for the rebated measure by the spillover rate to derive the IMC for the spillover measure.
- In cases where the evaluator believes the spillover measure incremental costs are materially different from the installed measure incremental costs (e.g., installation of measures that have no efficiency levels), the evaluator should use the estimated incremental project costs as the IMC for the spillover measure.

Normally, the sample-based estimates of IMCs for spillover measures should be extrapolated to the program level using sample weights. Then the total IMCs for rebated measures and the total IMCs for spillover measures should be summed and used in the TRC calculation.

For measures characterized by the IL-TRM, measure effective useful life (EUL) estimates should be based on the IL-TRM. For measures not characterized by the IL-TRM, evaluator can use either the EUL for similar measures or best professional judgment. In either case, the evaluator must provide the rationale for their choices.
3 Commercial, Industrial, and Public Sector Protocols

The table below lists Illinois non-residential programs and the free ridership protocol applicable to each program. If the design of a given program changes significantly, then it may mean that the NTG protocol listed for that program in this document is no longer appropriate. If that happens, the evaluator should follow the procedures outlined in Section 1.4: Diverging from the IL-NTG Methods. Note that the Core Non-Residential Spillover protocol described in Section 3.2 is generally applicable to most of these programs.

Table 3-1. Commercial, Industrial, and Public Sector Programs

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<td>3.5 Study-Based Protocol</td>
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3.1 Core Non-Residential Protocol

3.1.1 Core Non-Residential Free Ridership Protocol

Key considerations and guidelines for estimation of free ridership under this Core Non-Residential Free Ridership (FR) protocol are listed below:

- **Multiple Questions**: Evaluators will use program participant responses to multiple survey questions as inputs to the free ridership calculation algorithm. Evaluators will not use the response to a single question to establish a survey respondent as either a complete free rider or a complete non-free rider.

- **Program and Non-Program Factors**: Evaluators will administer survey questions to obtain respondent ratings on a numeric scale of the impact, influence, or importance on the decision to implement energy efficiency measures or take energy efficiency actions. A series of questions will focus on factors that the evaluator determines are a function of the program. Such program factors may, for instance, include the availability of the program incentive, technical assistance from program staff, program staff recommendations, Program Administrator marketing materials, and an endorsement or recommendation by a Program Administrator, account manager or program partner staff. Evaluators will also administer a series of questions to obtain respondent ratings, on a numeric scale of the impact, influence, or importance on the decision to implement energy efficiency measures, of different factors that the evaluator determines are not a function of the program. Such non-program factors may include, for example, previous experience with the measure, standard business or industry practice, and organizational policy or guidelines.

- **Vendor Recommendations**: Vendor recommendations may also be a program factor to the extent that such recommendations are a function of the program. Vendors include trade allies, contractors, distributors, suppliers, and other market actors involved in the selection and installation of program-incented equipment on behalf of the participant. The evaluator may administer survey questions to vendors to verify their involvement with participant projects and to obtain their ratings—on a numeric scale—of the impact, influence, or importance of the program on the decision to recommend the energy efficiency measures to the program participant.

- **Consistency Checks**: Evaluators should administer survey questions as checks on the consistency of responses associated with a core free ridership assessment methodology. Evaluators may also reference available quantitative and qualitative data, including consistency check data, to perform documented modifications to individual free ridership estimates resulting from the application of a core free ridership assessment methodology.

- **Quality Control Review**: For programs involving large, complex projects and decision-making, after all the survey data collection has been completed and preliminary NTGRs have been computed using the standard calculation procedures, a quality control review is completed. All quantitative and qualitative data is systematically and independently analyzed by a researcher who is familiar with the program, the individual site and the social science theory that underlies the decision maker survey instrument. They make an independent determination of whether the additional information justifies modifying the previously calculated NTGR score, and present any recommended modifications and their rationale in a well-organized manner, along with specific references to the supporting data. Circumstances that may justify a revision of the previously calculated NTGR score include: (1) significant inconsistencies exist between one of the scores that may lead to elimination of the score that is an outlier; (2) the emerging “story” from the qualitative data is in conflict with the quantitative data, thereby requiring a callback to the customer to resolve the inconsistency and a revision to the original scoring based on the new information; or (3) the entire set of results for an interview are inconsistent, the data are too disparate and would not be helped with a callback. In such cases, a recommendation is made to remove that sample point and replace it with a back-up point.
3.1.1.1 Core Free Ridership Scoring Algorithm

The Core Non-Residential FR protocol combines three scores that test different ways of approaching free ridership: the Program Components FR Score, the Program Influence FR Score, and the No-Program FR Score. The three scores are combined to calculate the final free ridership value.

Two options for combining the three scores are shown graphically in Figure 3-1 and Figure 3-2. These two options use different specifications to account for the impact of the program on project timing (referred to as “deferred free ridership”; see also discussion in Section 3.1.1.1.4). Evaluators will calculate free ridership using both options, and will select one option for purposes of calculating the annual incremental energy savings for comparing to the legislated goal.33

Evaluators will submit participant survey and net savings analysis data to the Illinois NTG Working Group. The group will analyze these data for the purpose of further refining the protocol and potentially reducing the number of alternative algorithm input specifications.

Figure 3-1. Core Free Ridership Algorithm 1

\[
\text{Final Free Ridership Value (0-1)} = \frac{(\text{Program Components FR Score (0-1)} + \text{Program Influence FR Score (0-1)} + \text{No-Program FR Score (0-1)} \times \text{Timing Adjustment 1})}{3}
\]

33 As defined in 220 ILCS 5/8-103 and 220 ILCS 5/8-104.
3.1.1.1.1 Program Components FR Score

Evaluators will administer survey questions to obtain participants’ rating of the importance of various factors on the decision to implement energy efficiency measures. The numeric scales shall range from 0 to 10, where 0 means “not at all important” and 10 means “extremely important”. The various factors referenced in the survey will include those that the evaluator determines are program factors and non-program factors that could potentially impact the participant decision making process. A participant rating shall be obtained for each relevant program and non-program factor.

Evaluators will calculate the “Program Components FR Score” for each survey respondent using the following equation:

\[
\text{Program Components FR Score} = 1 - \left(\frac{\text{Maximum Program Factor Rating}}{10}\right).
\]

These scores can range from 0 (no free ridership) to 1 (full free rider). Since the algorithm uses the numerical rating for the Program Component receiving the highest score, it is important that such scoring be accurate. To facilitate this, the scores feeding into the Program Components FR Score calculation can be enhanced by adjusting survey wording and adding consistency checks around specific program components to seek clarification on how they influenced decisionmaking. For those program components receiving scores of 8, 9 or 10, additional questions can be included to determine why that specific score was given, and further, how that Program Component specifically influenced the participant’s decision to upgrade to energy efficient equipment.

Evaluation reports should list all factors considered program and non-program factors. Evaluators must document why factors were treated as program factors or non-program factors.

3.1.1.1.2 Program Influence FR Score

Evaluators will administer a survey question that asks respondents to quantify the importance of the program on the decision to implement energy efficiency measures relative to the importance or impact of non-program factors. Respondents will be asked to allocate a total of 100 points to the program and to non-program factors. The points allocated to the program by the participants are the “Program Points.” Evaluators will calculate the “Program Influence FR Score” as 1 - (Program Points/100). This score can range from 0 (no free ridership) to 1 (full free rider).

3.1.1.1.3 No-Program FR Score

Evaluators will administer a counterfactual likelihood survey question to obtain respondent ratings on a 0 to 10-point numeric scale (where 0 means “not at all likely” and 10 means “extremely likely”) of the likelihood of the respondent to implement the exact same energy efficiency measures in the absence of the program. Evaluators will calculate the “No-Program FR Score” as the numeric score of the likelihood of the respondent to implement
specified energy efficiency measures in the absence of the program divided by 10. This score can range from 0 (no free ridership) to 1 (full free rider).

Note that under one of the two deferred free ridership specifications (see next subsection), a timing adjustment is applied to the “No-Program FR Score.” Under this specification, the resulting score is referred to as the “Adjusted No-Program FR Score.”

3.1.1.4 Timing and Deferred Free Ridership

Evaluators will ask about the likely timing of measure installation in the absence of the program in two different ways. This is referred to as the counterfactual timing question since the evaluators are asking the respondent to speculate on what might have happened within a particular timeframe.

The first question will present a series of date ranges (e.g., within one year, between 12 months and 2 years, etc.) and ask the respondent to pick one representing their best estimate of when the measure would have been implemented in the absence of the program. The free ridership algorithm uses the midpoint of each date range, referred to as “Number of Months Expedited” below. For respondents that report accelerated adoption due to the program, this variable can take on values from 6 to 48 months.

The second question will prompt the respondent to use a 0 to 10-point numeric scale to report the likelihood, in the absence of the program, of implementing the same measure within 12 months of when it was actually implemented. This is the “Likelihood of Implementing within One Year” in the formulas below.

Evaluators will use the Likelihood of Implementing within One Year and/or the Number of Months Expedited variables to calculate two alternative ways of accounting for deferred free ridership:

1) Calculate Timing Adjustment 1 as equal to:

\[ 1 - \frac{(Number\ of\ Months\ Expedited - 6)}{42} \]

Timing Adjustment 1 is multiplied by the No-Program FR Score; it can range from 0 (full deferred free ridership) to 1 (no deferred free ridership). The application of Timing Adjustment 1 is shown in Figure 3-1.

2) Calculate Timing Adjustment 2 as equal to:

\[ 1 - \left(\frac{(Number\ of\ Months\ Expedited - 6)}{42}\right) \times \left(\frac{(10 - Likelihood\ of\ Implementing\ within\ One\ Year)}{10}\right) \]

Timing Adjustment 2 is multiplied by the average of the Program Components FR Score, the Program Influence FR Score, and the No-Program FR Score; it can range from 0 (full deferred free ridership) to 1 (no deferred free ridership). The application of Timing Adjustment 2 is shown in Figure 3-2.

How these timing adjustments are accounted for in the calculation of the Final FR Value is described below in the subsection “3.1.1.2 Construction of Core Free Ridership Value.”

3.1.1.5 Consistency Checks

Respondents may be asked one or more questions to facilitate understanding and potentially reconcile apparently inconsistent responses. Some questions may be asked of all respondents; others may be asked when previous answers appear inconsistent. Evaluators should report on the amount of inconsistency encountered and on the resolution to inform future protocol revisions. Three consistency checks are outlined below.

Program Influence/Program Components Consistency Check

A Program Influence/Program Components consistency check is triggered when the following conditions are met:

1) The number of Program Points (supporting calculation of the Program Influence FR Score) is greater than 70; and

2) No program factor is rated greater than 2.

A Program Influence/Program Components consistency check is also triggered by the following conditions being met:
1) The number of Program Points (supporting calculation of the Program Influence FR Score) is less than 30; and
2) At least one program factor is rated greater than 7. In this instance, the highest-rated program factor(s) with a rating of greater than 7 will be referenced in the consistency check question.

**Program Components/No-Program Consistency Check**

A Program Components/No-Program consistency check is triggered when the following conditions are met:

1) The likelihood of installing the exact same equipment without the program (supporting calculation of the No-Program FR Score) is greater than 7; and
2) At least one program factor is rated greater than 7.

A Program Components/No-Program consistency check is also triggered when the following conditions are met:

1) The likelihood of installing the exact same equipment without the program (supporting calculation of the No-Program FR Score) is less than 3; and
2) No program factor is rated greater than 2.

**Timing of Installation Decision/Level of Program Attribution Consistency Check**

The survey should contain a question to ask whether the respondent learned about the program after finalizing project specifications, including, where applicable, equipment efficiency level and number of units. The Timing of Installation Decision/Level of Program Attribution consistency check is triggered by the following conditions being met:

1) A respondent learned about the program after finalizing project specifications; and
2) Any of the following occur:
   a) The number of Program Points (supporting calculation of the Program Influence FR Score) is greater than 70;
   b) The likelihood of installing the exact same equipment without the program (supporting calculation of the No-Program FR Score) is less than 3; or
   c) At least one program factor is rated greater than 7.

When the Timing of Installation Decision/Level of Program Attribution consistency check is administered, if the respondent rating of the importance of the vendor on the decision to implement the project is greater than 7, then an open-ended question will be triggered to obtain information regarding the role the vendor played in the participant decision to implement the project.

### 3.1.1.2 Construction of Core Free Ridership Value

This protocol designates two options of constructing the core free ridership value. Evaluators will calculate free ridership using both options and will select one option for purposes of calculating the annual incremental energy savings for comparing to the legislated goal. Evaluators will present the results of both estimates of free ridership in EM&V reporting.

Evaluators will calculate free ridership values in the following two ways:

1) Core FR Algorithm 1 = AVERAGE([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score*Timing Adjustment 1])
2) Core FR Algorithm 2 = AVERAGE([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score]) * Timing Adjustment 2

The two Core FR Algorithms listed above are graphically presented in Figure 3-1 and Figure 3-2, respectively.
3.1.1.3 Vendor Influence in the Free Ridership Calculation

3.1.1.3.1 Treatment of Participant’s Rating of Vendor in the Program Components FR Score of the Core FR Algorithm

The Program Components FR Score of the participant Core FR algorithm is based on participant ratings of program and non-program factors. Vendors\(^{34}\) often receive a high rating for their influence on the participant’s decision to install the efficient measure. To implement the Core FR algorithm, the evaluator needs to decide whether the vendor rating should be considered a program factor or a non-program factor. This section outlines three scenarios for the treatment of the participant’s rating of a vendor in the Program Components FR Score of the Core FR algorithm.

Scenario #1: Vendors are automatically considered a program factor

The vendor is considered a program factor in the calculation of the Program Components FR Score in the FR algorithm if the program meets specific criteria, which could include the following:

1. Trade allies are an integral component of program delivery, as supported by program logic
2. The trade ally network consists of a limited number of Program Administrator-selected, pre-approved trade allies
3. Only trade allies can implement projects and submit applications on behalf of the customer
4. Trade allies complete signed agreements with the Program Administrator
5. Trade allies complete program-sponsored training

In these cases, the vendor is automatically considered a program factor, and no additional input from the vendor is needed regarding the customer’s decision-making process related to the project. The participant’s influence rating for the vendor goes directly into the Program Components FR Score algorithm as a program factor (if it is the highest rating given to any program factor).

Scenario #2: Vendors are considered a program factor if the program influenced their recommendation to implement the efficient project

For programs that have a trade ally network, but do not meet the conditions under Scenario #1 above, follow-up interviews with vendors may be used to determine if the vendor should be considered a program factor. To qualify for Scenario #2, a program’s trade ally network should meet the following conditions:

1. Trade allies are registered with the program
2. Trade allies typically complete signed agreements with the Program Administrator
3. Trade allies complete program-sponsored training
4. Trade allies drive program participation, as supported by program logic

In these cases, if the size of the project warrants a greater level of effort, a follow-up interview with the vendor may be used to determine if the participant’s rating of the vendor’s influence should be included as a program factor. A follow-up interview is triggered under the following conditions:

1. The participant rated the influence of the vendor as 8, 9, or 10 (on a scale from 0 to 10)
2. The rating the participant gave to vendor influence is higher than any of the program factor ratings

If completed, the interview should include the following questions:

**FR1a** On a scale of 0 to 10 where 0 is NOT AT ALL IMPORTANT and 10 is EXTREMELY IMPORTANT, how important was the <PROGRAM>, including incentives as well as program services and information, in influencing your decision to recommend that <CUSTOMER> install the energy efficient <MEASURE> at this time?

\(^{34}\) Vendors include trade allies, contractors, distributors, suppliers, and other market actors involved in the selection and installation of program-incented equipment on behalf of the participant.
FR1b On the same scale, how important was your firm’s past participation in an incentive or study-based program sponsored by <PROGRAM ADMINISTRATOR>?

FR2 And using a 0 to 10 likelihood scale where 0 is NOT AT ALL LIKELY and 10 is EXTREMELY LIKELY, if the <PROGRAM>, including incentives as well as program services and information, had not been available, what is the likelihood that you would have recommended this specific <MEASURE> to <CUSTOMER>?

FR3a Approximately, in what percent of projects did you recommend <MEASURE> BEFORE you learned about the <PROGRAM>?

FR3b And approximately, in what percent of projects do you recommend <MEASURE> now that you have worked with the <PROGRAM>?

The interview will also include consistency checks, if the vendor provides inconsistent responses to these questions.

The vendor is viewed as a program factor and the rating the participant provided for the vendor goes into the Program Components FR Score algorithm as a program factor if, after consideration of any consistency checks:

1. The response to Q. FR1a or FR1b is 8, 9, or 10

OR

2. The response to Q. FR2 is 0, 1, or 2

OR

3. The difference between the responses to FR3b and FR3a is 80% or greater

If none of these conditions are met, the rating the participant provided for the vendor does not go into the Program Components FR Score algorithm as a program factor.

In the event that an interview is not completed (e.g., the size of the project did not warrant a vendor interview or the vendor could not be reached), the evaluation reports should explain how the rating the participant provided for the vendor was treated. Guidelines for these situations may be added to this document in the future.

**Scenario #3: Vendors are considered a non-program factor**

For programs that do NOT have a trade ally network that meets the conditions under Scenario #2, vendors are considered a non-program factor. In these cases, the participant’s rating of the vendor does not go directly into the Program Components FR Score algorithm as a program factor.

### 3.2 Core Non-Residential Spillover Protocol

Spillover refers to energy savings associated with energy-efficient equipment installed by consumers who were influenced by an energy efficiency program, but without direct intervention (e.g., financial or technical assistance) from the program.

To place the spillover protocols in context, we begin by defining the NTGR as:

\[
NTGR = (1 - \text{Free Ridership Value} + \text{PSO Rate} + \text{NPSO Rate})
\]

Where:

\[
\text{PSO Rate} = \text{Participant spillover rate}
\]

\[
\text{NPSO Rate} = \text{Nonparticipant spillover rate}
\]

The term (1-Free Ridership) is referred to as the Core NTGR for an efficiency program.

#### 3.2.1 Core Participant Spillover Protocol

The Core Participant Spillover protocol is generally applicable to most commercial, industrial, and public sector
programs.

3.2.1.1 Research Methods

Data collection approach. An initial determination of participant spillover may be made based on self-reported findings from surveys of program participants. At a minimum, surveys collecting data pertaining to participant spillover will obtain general information on the specific measures installed and information substantiating their attribution to an energy efficiency program. Research on the specific characteristics of the energy efficient equipment installed and the baseline and operating conditions needed to estimate savings may be done in one of two ways: 1) a detailed battery of measure specific questions may be administered as part of the initial survey; or 2) a separate in-depth follow-up interview may be conducted by the engineer or analyst responsible for the energy savings calculation. In either case, an engineer or analyst will use the collected data to develop an estimate of spillover savings for each project.

Sample Frame. One target for participant spillover research may be the most recent year’s program participants who have been sampled for free ridership or process surveys. In the case where a stand-alone spillover study is being conducted, the sample frame may be broader and include those whose participation occurred during the time period of two prior program years.

Because evaluated spillover energy impacts associated with the sample are being extrapolated to the program population, it is important that the sample frame be limited to participating customers for which spillover may potentially be claimed.

Sample frames should be constructed in accordance with the following guidelines:

- Self-directing customers as defined by 220 ILCS 5/8-104(m) should be excluded from the sample frame for natural gas spillover.
- Customers of municipal electric utilities should be excluded from the sample frame for electric spillover.

Timing of Data Collection. Evaluators may either administer the participant spillover module as part of a comprehensive net-to-gross survey, or they may elect to implement it separately. A follow-up in-depth interview may also be conducted by an engineer or analyst to obtain additional details needed to quantify savings. Optimally, the spillover inquiry should be timed in order to allow sufficient time for spillover to occur; at a minimum, three months after the program-incented measure is installed. Projects installed up to two years after program participation occurred may be counted as spillover, provided it can be substantiated.

3.2.1.2 Approach for Identifying and Quantifying Spillover

Attribution Criteria. Program attribution is determined by the responses to the following two survey questions:

1. How important was your experience in the <PROGRAM> in your decision to implement this measure, using a scale of 0 to 10, where 0 is not at all important and 10 is extremely important?

2. If you had not participated in the <PROGRAM>, how likely is it that your organization would still have implemented this measure, using a 0 to 10 scale, where 0 means you definitely WOULD NOT have implemented this measure and 10 means you definitely WOULD have implemented this measure?

The response to the first question cited above is “Measure Attribution Score 1,” and the response to the second question cited above is “Measure Attribution Score 2.”

There are two methods by which the attribution may be calculated:

1. Program attribution is established if the average of Measure Attribution Score 1 and (10 – Measure Attribution Score 2) exceeds 5.0; either the Measure Attribution Score 1 or (10 – Measure Attribution Score 2) must exceed 5.0.

Note that the threshold value for counting spillover has been lowered from 7.0 to 5.0. The rationale for this lower threshold is: (1) the value of >5 is a strong indicator of program influence on the decision to install non-
Attribution Score 2) could be below 5.0—as long as the average is greater than 5.0, the threshold is met. If the average is greater than 5.0, 100% of the measure energy savings referenced in the question are considered to be attributable to the program. If the average is not greater than 5.0, none of the measure energy savings are considered to be attributable to the program.

2. An attribution rate may be calculated as equal to the sum of Measure Attribution Score 1 and (10 – Measure Attribution Score 2), divided by 20. For instance, if the attribution rate is 0.3, then 30% of the measure energy savings referenced in the question are considered to be attributable to the program.

Program attribution option 2 must be used in cases in which evaluators have performed the data collection and analysis required to attribute energy savings using option 2 identified above.

Calculation of Spillover Measure Energy Savings. Energy savings of spillover measures shall be calculated in one of two ways.

1. Those addressed in the IL-TRM shall be calculated in accordance with the methods and algorithms specified in the IL-TRM, and shall reference the IL-TRM-defined time-of-sale or new construction baseline.

2. For measures not addressed in the IL-TRM, evaluators shall quantify savings using accepted industry-wide savings methods that conform to IPMVP or other industry protocols and documents.

Evaluators will make every effort to ensure that there is no double-counting of participant spillover energy savings across multiple sources of participant and nonparticipant spillover (such as participating customer and trade ally surveys) and will document that effort.

Measure implementation must have occurred within one year of the participant spillover study data collection effort in order to be countable as participant spillover.

For the purposes of accounting for spillover savings attributable to a program, spillover will only be quantified for measures implemented within the Program Administrator’s service territory.

3.2.1.3 Key Participant Spillover Survey Questions

The Participant Spillover question module is designed to be a general inquiry that seeks to: (1) assess whether additional energy efficiency improvements were implemented since the rebated project was completed; (2) confirm that these measures either had not received program incentives, or that there were no plans to submit them for program incentives in the future; (3) gather basic information about the additional energy efficiency measures (e.g., their type, size, quantities, and energy efficiency rating); and (4) establish program attribution.

The basic question structure is shown below. The measure-specific questions can be repeated in order to capture multiple measures. Note that there is considerable flexibility to tailor the questions to specific types of applications and programs.

1. Since your participation in the <PROGRAM>, did you implement any ADDITIONAL energy efficiency improvements at this facility or at your other facilities within <PROGRAM ADMINISTRATOR>’s service territory that did NOT receive incentives through <PROGRAM>?

2. What measures did you implement without an incentive?

MEASURE-SPECIFIC QUESTIONS [repeated for each spillover measure]36

36 Example questions to gather engineering information to support the calculation of spillover savings may be
1. How important was your experience in the <PROGRAM> in your decision to implement this <MEASURE>? Please use a scale of 0 to 10, where 0 is not at all important and 10 is extremely important.

2. Can you explain how your experience with the <PROGRAM> influenced your decision to install this additional high-efficiency measure?

3. If you had not participated in the <PROGRAM>, how likely is it that your organization would still have implemented <MEASURE>? Please use a 0 to 10, scale where 0 means you definitely WOULD NOT have implemented this measure and 10 means you definitely WOULD have implemented this measure.

4. How many of <MEASURE> did you install?

5. Questions to further define the measure (as applicable):
   a. Type
   b. Efficiency
   c. Size
   d. Other attributes

6. Can you briefly explain why you decided to install this energy efficiency measure on your own, rather than going through the <PROGRAM>?

3.2.1.4 Reporting of Results

Evaluators will report the following information relating to participant spillover data collection and analysis in annual EM&V reporting: 1) the number of participants surveyed; 2) the number of survey respondents reporting spillover; 3) the number of survey respondents who meet the spillover attribution threshold; 4) the number of respondents for which spillover savings were actually quantified; 5) the spillover savings for each project and overall; and 6) the spillover rate. The term (1-Free Ridership) is referred to as the Core NTGR.

The annual EM&V report should also describe the means by which the participant spillover rate is calculated. Two possible approaches are:

(1) Add the participant spillover rate to each project’s Core NTGR. The project-level NTGRs are then weighted by each project’s ex ante or ex post (if available) gross savings as a share of the total. This savings-weighted NTGR can then be applied to the ex post gross savings of the participant population. If the sample is stratified, sampling weights must be applied before applying the NTGR to the ex post gross savings of the participant population.

(2) Estimate program spillover effects by summing overall project-level spillover estimates for the sample and dividing this sum by the total ex ante or ex post (if available) gross savings for the sample to produce the participant spillover rate. This participant spillover rate can be added to the Core NTGR for the sample to yield the NTGR. If the sample is stratified, sampling weights must be applied before applying the NTGR to the ex post gross savings of the participant population.

In both cases, the participant spillover rate must be calculated at the project level for Option 1 or at the program level for Option 2, using the following formula.

\[
\text{Participant Spillover Rate} = \frac{\text{ISO} + \text{OSO in sample}}{\text{Ex Post Gross Impacts in sample}}
\]

Where:

\[
\text{ISO} = \text{Inside participant spillover}
\]

accessed here: [http://www.ilsag.info/il_ntg_methods.html](http://www.ilsag.info/il_ntg_methods.html)
OSO = Outside participant spillover

3.2.2 Core Nonparticipant Spillover Protocol

The evaluation may perform research to measure nonparticipant spillover (NPSO). Evaluators will make efforts to ensure that there is no double-counting of energy savings across multiple sources and will document those efforts.

3.2.2.1 Core Nonparticipant Spillover Protocol – Measured from End Users

NPSO for end users is defined as the energy savings that are achieved when a nonparticipant end user—as a result of the influence of a Program Administrator’s programs—implements energy efficiency measures outside of the Program Administrator’s programs.

One option for the evaluator would be to survey nonparticipating customers and estimate spillover savings for any efficient measures installed that respondents are able to attribute to specific Program Administrator programs. However, in many cases, nonparticipants might find it difficult, if not impossible, to reliably attribute any of their installations to the influence of a specific Program Administrator program. If an evaluator suspects that nonresidential nonparticipants will not be able to reliably attribute spillover savings to any particular Program Administrator program, a second option would be to survey nonparticipants and estimate spillover savings from the installation of efficient measures that respondents are able to attribute to their general knowledge of the Program Administrator incentives and information, regardless of the particular program source. These protocols are written assuming that the NPSO for end users will be estimated using this second option.

Note that this protocol does not address estimating spillover for upstream and midstream programs where the end user is assumed to be completely ignorant of any Program Administrator influence. Of course, when considered feasible, evaluators are free to estimate spillover and spillover rates at the program-specific level with the suggested questions presented in Section 3.2.2.1.2 modified appropriately.

3.2.2.1.1 Research Methods

Data Collection Approach. An initial determination of spillover may be made based on self-reported findings from surveys of nonparticipants. At a minimum, surveys collecting data pertaining to nonparticipant spillover will obtain general information on the specific measures installed and information substantiating the influence of the Program Administrator on the installation decision. Research on the specific characteristics of the energy efficient equipment installed and the baseline and operating conditions needed to estimate savings may be done in one of two ways: (1) a detailed battery of measure specific questions may be administered as part of the initial survey, or (2) a separate in-depth follow-up interview may be conducted by the engineer or analyst responsible for the energy savings calculation. Projects installed within the last two years of the nonparticipant spillover study data collection effort may be counted as spillover, provided program attribution and energy savings can be substantiated. In either case, an engineer or analyst will use the collected data to develop an estimate of spillover savings for each project.

Sample Frame. The sample frame for nonparticipant end user spillover research is composed of customers who have not participated in any programs within the last three years. Because evaluated spillover savings associated with the sample are being extrapolated to the nonparticipant population, it is important that the sample frame be limited to nonparticipants for whom spillover may potentially be claimed.

Sample frames should be constructed in accordance with the following guidelines:

37 See http://www.ilsag.info/il_ntg_methods.html for detailed example questions designed to collect information required to estimate spillover savings for a variety of measures.
• Self-directing customers as defined by 220 ILCS 5/8-104(m) should be excluded from the sample frame for natural gas spillover.
• Customers of municipal electric utilities should be excluded from the sample frame for electric spillover.
• Entities eligible to participate in the Illinois Department of Commerce and Economic Opportunity programs will not be included in sample frames for the study of nonparticipant spillover attributable to utility-administered programs.
• Entities eligible to participate in the utilities’ programs will not be included in sample frames for the study of nonparticipant spillover attributable to programs administered by the Department of Commerce and Economic Opportunity.

Timing of Data Collection. Evaluators might administer the nonparticipant end user spillover study in parallel with the program impact evaluation, potential study or saturation study research, or at a different time.

3.2.2.1.2 Approach for Identifying and Quantifying Spillover

Key Nonparticipant Spillover Survey Questions. The nonparticipant end user spillover question module is designed to be a general inquiry that seeks to: (1) assess whether additional energy efficiency improvements were implemented during the study period; (2) confirm that these measures had not received program incentives and that there were no plans to submit them for program incentives in the future; (3) gather basic information about the additional energy efficiency measure(s), e.g., the type, size, quantities, and energy efficiency rating; and (4) establish the Program Administrator importance ratings. Note that while the example questions can be customized to assess the influence of a specific program in the Program Administrator portfolio, they are currently worded to capture influence of the Program Administrator, regardless of program source.

Below are example questions that might be used in a nonparticipant spillover survey. They are grouped by the following topics:

- **Threshold conditions**: Is there some credible evidence that it was at least possible for the Program Administrator to have influenced the decision to install additional energy efficient measures?
- **Measure description**: Enough information needs to be collected for the measure and its operation to support a credible estimate of savings
- **Attribution**: Is there credible evidence that the Program Administrator had substantial influence on the end user’s decision to install the efficient measure outside of any of the programs in the Program Administrator portfolio?

Threshold Conditions. Spillover cases are identified using a threshold approach in which certain minimal conditions must be met for a customer’s installation to be considered for spillover. The following are example questions that evaluators may use (individually or in combination) to determine that program administrator influence on the installation is possible:

1. Before installing these measures, did you know that <PROGRAM ADMINISTRATOR> offers energy efficiency programs, incentives, and information to help their business customers make energy efficiency improvements at their facilities?
2. <PROGRAM ADMINISTRATOR> offers incentives for energy efficient equipment upgrades and improvements through its <PORTFOLIO NAME> programs. Before installing these measures, had you heard about the <PORTFOLIO NAME> programs?

If the answer to either question is “yes”, then the threshold condition is met.

Measure Description. The interview (either the initial interview or a separate in-depth follow-up interview) can be used to determine the following basic attributes (as applicable) required to support a credible estimate of savings:

1. Type
2. Efficiency
3. Size
4. Other attributes

The named measure(s) must represent equipment that is more energy efficient than either: (1) equipment
required by codes or standards; (2) industry-standard practice for certain types of equipment; or (3) for Custom measures, the minimum efficiency equipment available to meet the customer’s requirements. For detailed example questions designed to collect engineering information required to estimate spillover savings for a variety of measures, see http://www.ilsag.info/il_ntg_methods.html.

**Attribution.** The following questions are suggested to assess attribution. These questions should be asked separately for each potential spillover measure:

1. Earlier you mentioned that <PROGRAM ADMINISTRATOR> offers incentives to customers for installing energy efficient equipment, and also provides information to customers to help them reduce their energy usage. Thinking about all of the reasons you chose to install the energy efficient <MEASURE>, did your knowledge of these incentives and information available through <PROGRAM ADMINISTRATOR> have ANY INFLUENCE on your decision to install <MEASURE>?

   **ASK IF Q1= YES**

2. Using a scale of 0 to 10, where 0 is not at all influential and 10 is extremely influential, how much influence did your knowledge of the incentives and information <PROGRAM ADMINISTRATOR> offers have on your decision to install your energy efficient <MEASURE>?

3. Just to make sure that we understand you correctly, please answer the following hypothetical question. If you had you NOT known about the incentives and information <PROGRAM ADMINISTRATOR> offers, would you still have installed your energy efficient <MEASURE>? Please use a scale of 0 to 10, where 0 means you definitely WOULD NOT have installed your energy efficient <MEASURE> and 10 means you definitely WOULD have done so.

**Consistency Checks**

Respondents may be asked one or more questions to facilitate understanding and potentially reconcile apparently inconsistent responses. Evaluators should report on the amount of inconsistency encountered and on the resolution to inform future protocol revisions.

**ASK IF Q2>7 AND Q3>7 OR Q2<3 AND Q3<3**

4. In your own words, can you explain HOW your knowledge of the incentives and information <PROGRAM ADMINISTRATOR> offers influenced your decision to purchase or install your energy efficient <MEASURE>?

The evaluation analyst will assess the response to this open ended question and its consistency with the other questions, and, if warranted based on clear additional information, they will adjust the score based on expert judgment. If an inconsistency exists and the open-ended response does not resolve the inconsistency, the respondent will be removed from the calculation. All instances of this occurring should be documented in the final report. Additional consistency checks, triggered and resolved within the survey with additional questions to participants, remain optional.

**Nonparticipant End User Spillover Algorithm.** The response to question #2 cited above is “Measure Attribution Score 1,” and the response to question #3 cited above is “Measure Attribution Score 2."

There are two methods by which the attribution may be calculated:

1. Provided that the open-ended responses do not contradict influence of the Program Administrator, spillover is considered to be attributable to the Program Administrator if the average of the Measure Attribution Score 1 and (10 – Measure Attribution Score 2) exceeds 5.0\(^\text{38}\); either the Measure Attribution

\[\text{Note that the same 5.0 threshold value is being used for both Participant and Nonparticipant Spillover.}\]
Score 1 or (10 – Measure Attribution Score 2) could be below 5.0—as long as the average is greater than 5.0, the threshold is met. If the average is greater than 5.0, 100% of the measure energy savings referenced in the question are considered to be attributable to the Program Administrator. If the average is not greater than 5.0, none of the measure energy savings are considered to be attributable to the Program Administrator.

2. Provided that the open-ended responses do not contradict influence of the Program Administrator, the attribution rate is calculated as equal to the sum of Measure Attribution Score 1 and (10 – Measure Attribution Score 2), divided by 20. For instance, if the attribution rate is 0.3, then 30% of the measure energy savings referenced in the question are considered to be attributable to the Program Administrator.

**Calculation of Spillover Measure Energy Savings.** Energy savings of spillover measures shall be calculated in one of two ways.

1. Those addressed in the IL-TRM shall be calculated in accordance with the methods and algorithms specified in the IL-TRM, and shall reference the IL-TRM-defined time-of-sale or new construction baseline.
2. For measures not addressed in the IL-TRM, evaluators shall quantify savings using accepted industry-wide savings methods that conform to IPMVP and other industry protocols and documents.

Evaluators will make every effort to ensure that there is no double-counting of nonparticipant spillover energy savings across multiple sources of nonparticipant spillover reporting (such as nonparticipating customer and trade ally surveys) and will document that effort.

Measure implementation must have occurred within the last two years of the nonparticipant spillover study data collection effort in order to be countable as nonparticipant spillover.

For the purposes of accounting for spillover savings attributable to the Program Administrator, spillover will only be quantified for measures implemented within the Program Administrator’s service territory.

**3.2.2.1.3 Reporting of Results**

Evaluators will report the following information relating to nonparticipant spillover data collection and analysis in annual EM&V reporting: 1) how the sample frame was defined, 2) the number of customers surveyed; 3) the number of survey respondents reporting spillover; 4) the number of survey respondents who meet the spillover attribution threshold; 5) the number of respondents for which spillover savings were actually quantified; 6) the spillover savings for each project and overall; 7) the nonparticipant spillover rate, and 8) the calculation of the weights used to extrapolate the spillover to the population of nonparticipants from which the sample was drawn.

The EM&V report should also describe the means by which the nonparticipant spillover (NPSO) rate is calculated. For each sampled site, the verified spillover savings should be summed across measures to derive the total end user NPSO for the sampled sites. The estimate of site-level end user NPSO for the entire sample is then extrapolated to the entire nonparticipant population using sampling weights.

There are two options for using the estimated NPSO.

1. Allocate the portfolio-level spillover savings to individual programs in the portfolio based on each program’s share of the ex post gross savings. For each program, the spillover rate could then be calculated for each program using the equation below in which the spillover allocated to each program would be the numerator and the ex post program-specific gross savings would be the denominator.

   \[
   \text{Program – Specific NPSO Rate} = \frac{\text{NPSO Program} – \text{Specific}}{\text{Ex Post Gross Impacts Program} – \text{Specific}}
   \]

   This includes all samples sites including those that reported no spillover savings.
The spillover-adjusted NTGR for each program could then be used to adjust the Core NTGR for each program before calculating the TRC. In calculating the Program-Specific NPSO Rate, the numerator and denominator must be consistent in terms of the time period of measure implementation/potential implementation. While this time period must be within the last two years, it may be for a period of less than two years.

2. The NPSO Rate is calculated at the Sector level. The estimated energy savings associated with program-attributable spillover measures implemented during the study period by the entire nonparticipant population is divided by the ex post gross impacts for all the nonresidential programs in the portfolio occurring during the study period. The C&I Sector NPSO Rate is calculated using the following equation

\[ \text{Portfolio NPSO Rate} = \frac{\text{NPSO}_\text{Portfolio}}{\text{Ex Post Gross Impacts}_\text{Portfolio}} \]

The NPSO rate could then be used to adjust the portfolio core NTGR before calculating the portfolio TRC. Again, in calculating the Portfolio NPSO Rate, the numerator and denominator must be consistent in terms of the time period of measure implementation/potential implementation. While this time period must be within the last two years, it may be for a period of less than two years.

3.3 Small Business Protocol

3.3.1 Free Ridership

The FR algorithm for non-residential small business programs will follow the Core Non-Residential FR Protocol, with the following exceptions:

1. To reduce respondent burden, the Program Influence FR Score may be dropped from the Small Business FR algorithm. The influence of nonprogram factors will still be captured in the Program Components FR Score.

2. The counterfactual likelihood question (likelihood the participant would have installed the exact same energy efficiency equipment absent the program) may be preceded with a 0-10 scale question about the likelihood the participant would have installed any new equipment—either standard efficiency or high efficiency—on their own.
   a. If the participant provides a likelihood response of 0, then the No-Program FR Score for that participant is set to 0.
   b. If the participant provides a likelihood response of 1-10, then the participant is asked the same counterfactual questions (including the first timing question) as in the Core Non-Residential FR protocol.

3. To reduce respondent burden, the second question about timing (likelihood the participant would have installed the exact same energy efficiency equipment within 12 months) may be dropped. In this case, the only Deferred Free Ridership specification would be the one applying Timing Adjustment 1.

The diagram below, Figure 3-3, depicts the Small Business FR approach with the above exceptions implemented.
Figure 3-3. Small Business Free Ridership

\[(\text{Program Components FR Score} + (\text{No-Program FR Score} \times \text{Timing Adjustment 1})) / 2\]

Evaluators will calculate free ridership values for small business projects as follows:

1. If Program Influence FR Score is dropped:
   
   \[\text{FR} = \text{AVERAGE} \left(\frac{\text{Program Components FR Score}}{\text{No-Program FR Score}}\times\text{Timing Adjustment 1}\right)\]

2. If Program Influence FR Score is included:

   \[\text{FR} = \text{AVERAGE} \left(\frac{\text{Program Components FR Score}}{\text{Program Influence FR Score}}\times\text{No-Program FR Score}\times\text{Timing Adjustment 1}\right)\]

### 3.4 C&I New Construction Protocol

#### 3.4.1 Free Ridership

The FR algorithm for non-residential new construction programs will follow the Core Non-Residential FR protocol, with the following exception:

- The concept of project timing and deferred free ridership is not applicable to new construction projects.

As a result, the various deferred free ridership specifications outlined in Figure 3-1 and Figure 3-2 will not be included in the free ridership estimation for new construction projects.

Evaluators will calculate free ridership values for new construction projects as follows:

\[\text{FR} = \text{AVERAGE} \left(\frac{\text{Program Components FR Score}}{\text{Program Influence FR Score}}\times\text{No-Program FR Score}\right)\]

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40 New Construction programs intervene in the early phases of ongoing construction projects (i.e., after the decision to build has been made). As a result, participation in a New Construction program would not be expected to accelerate the construction of the new building.
3.5 Study-Based Protocol

3.5.1 Free Ridership

The FR algorithm for non-residential study-based programs (See Figure 3-4) will follow the Core Non-Residential FR protocol, with the following exceptions:

- The counterfactual likelihood question (Q.4 in Figure 3-5 and Figure 3-6, below) will be preceded by five questions.\(^{41}\)
- Q.1 A 0-10 scale question about the likelihood that the participant would have conducted the study absent the program will be included.

At the measure-group level, the following should be included:

- Q.2a A yes/no question to determine if the participant performs regular maintenance on the equipment treated through the program.
- Q.2b If the response to Q.2a is “yes,” a yes/no question to determine if the maintenance always includes the treatment provided through the program.
- Q.3a A yes/no question to determine if the participant had prior awareness of the performance issues identified through the study.
- Q.3b A 0-10 scale question about the participant’s level of familiarity with the recommended actions to rectify the performance issue.

The counterfactual likelihood question (Q.4 — likelihood the participant would have taken action absent the program) and the first counterfactual timing question (used to develop Timing Adjustment 1) will be asked at the measure-group level. Measure-group level responses will be aggregated to the project level, using savings-based weights.

There will be two options for developing the No-Program FR Score:

1. The measure-group level Adjusted No-Program FR Score will be developed following Algorithm 1 of the Core Non-Residential FR approach, using responses to the counterfactual likelihood question (Q.4) and Timing Adjustment 1.

2. The measure-group level No-Program FR Scores will be assigned, based on responses to Q.1, Q.2b, Q.3a, and Q.3b, as follows:
   a. If Q.2b = Yes, then No-Program FR Score = 1. This assumes that if the participant performs regular maintenance on the treated equipment and that maintenance always includes the issue addressed through the program, then the participant is a full free rider for that measure group for purposes of calculating the No-Program FR Score.
   b. If Q.3a = No and Q1 = 0 and Q.2b ≠ Yes, then No-Program FR Score = 0. This assumes that if the participant was not aware of the performance issue and had a zero likelihood of performing the study absent the program and their maintenance practices do not always include the issue addressed through the program, then the participant is not a free rider for that measure group for purposes of calculating the No-Program FR Score since they would not have found out about the issue absent the program.
   c. If Q.3b = 0 and Q1 = 0 and Q.2b ≠ Yes, then No-Program FR Score = 0. This assumes that if the participant had no familiarity with how to rectify the performance issue, had a zero likelihood of

---

\(^{41}\) It should be noted that the question numbering in Figure 3-5 and Figure 3-6 is for reference purposes only; the additional questions do not have to immediately precede the counterfactual likelihood question.
performing the study absent the program, and their maintenance practices do not always include the issue addressed through the program, then the participant is not a free rider for that measure group for purposes of calculating the No-Program FR Score since they would not have known how to address the issue absent the program.

d. For all other combinations of responses to Q.1, Q.2b, Q.3a, and Q.3b, the measure-group level Adjusted No-Program FR Scores will be developed following Algorithm 1 of the Core FR approach, using responses to the counterfactual likelihood question (Q.4) and Timing Adjustment 1.

Figure 3-4. Study-Based Free Ridership—Overview

\[(\text{Program Components FR Score} + \text{Program Influence FR Score} + (\text{No-Program FR Score} \times \text{Timing Adjustment 1})) / 3\]

- Importance of ... on decision to conduct study and perform RCx on your facility? 0-10
  - Program factors
  - Non-program factors

- Max Program Factor

- 1 - n/10

- How many points would you give to the importance of the program? 0-100

- 1 - n/100

- Program Components FR Score (0-1)

- Program Influence FR Score (0-1)

- Average

- Final Free Ridership Value (0-1)

See diagrams below for options of calculating the No-Program FR Score.
Figure 3-5. Study-Based Free Ridership—No-Program FR Score Option #1

Q.1 If the program had not been available, what is the likelihood that you would have conducted the study on your own? 0-10

For each measure group:

Q.2a Do you perform regular maintenance on [EQUIPMENT], either through facility staff or a maintenance contractor? 
  Ask if Yes 
  Q.2b Does this maintenance always include [MEASURE]?
  Ask if No

Q.3a Were you aware of the performance issue identified through the study PRIOR to conducting it?

Q.3b How familiar were you with the recommended measure/actions to rectify the issue? 0-10

Q.4 If the program had not been available, what is the likelihood that you would have taken action on your own? 0-10

Adjusted Measure-Level No-Program FR Score (0-1)
Savings-weighted Average
Adjusted No-Program FR Score (0-1)

Timing Adjustment 1

Note that the orange arrows in this diagram indicate score assignments rather than survey skips.

Figure 3-6. Study-Based Free Ridership—No-Program FR Score Option #2

Q.1 If the program had not been available, what is the likelihood that you would have conducted the study on your own? 0-10

For each measure group:

Q.2a Do you perform regular maintenance on [EQUIPMENT], either through facility staff or a maintenance contractor? 
  Ask if Yes 
  Q.2b Does this maintenance always include [MEASURE]?
  Ask if No

Q.3a Were you aware of the performance issue identified through the study PRIOR to conducting it?

Q.3b How familiar were you with the recommended measure/actions to rectify the issue? 0-10

No AND Q1=0 AND Q.2b<>Yes
FR = 1

Yes

Q.4 If the program had not been available, what is the likelihood that you would have taken action on your own? 0-10

Measure-Level No-Program FR Score
Timing Adjustment 1

Adjusted Measure-Level No-Program FR Score (0-1)
Savings-weighted Average
Adjusted No-Program FR Score (0-1)

Note that the orange arrows in this diagram indicate score assignments rather than survey skips.

Evaluators will calculate free ridership values for study-based programs as follows:
FR = AVERAGE ([Program Components FR Score], [Program Influence FR Score], [No-Program FR Score * Timing Adjustment 1])

Evaluators will develop estimates of free ridership based on the two No-Program FR Score options outlined above. Evaluators will select one of these for purposes of calculating the annual incremental energy savings for comparing to the legislated goal. Evaluators will present the results of both estimates of free ridership in EM&V reporting.

3.6 Technical Assistance Protocol

This protocol is applicable to programs that provide technical assistance to encourage the adoption of energy efficiency measures in non-residential facilities, but do not provide financial incentives.

Program-attributable savings from Technical assistance programs are achieved when a program participant—as a result of the program’s influence via the training or technical assistance provided—undertakes energy efficiency improvements on their own, without any direct financial assistance from any other Illinois energy efficiency program.

An initial determination of program-attributable savings is made based on self-reported findings from surveys of program participants. At a minimum, surveys collecting data pertaining to participant measure implementation will obtain general information on the specific measures installed and information substantiating their attribution to the program. Research on the specific characteristics of the energy-efficient equipment installed and the baseline and operating conditions needed to estimate savings may be done in one of two ways: 1) a detailed battery of measure specific questions may be administered as part of the initial survey; or 2) a separate in-depth follow-up interview may be conducted by the engineer or analyst responsible for the energy savings calculation. These collected data may be augmented by detailed facility and measure characteristics if provided by program staff.

3.6.1 Free Ridership

- The FR algorithm for Technical Assistance programs is identical to the Core Non-Residential FR protocol, with the following exception:
  - For the Program Components score, the list of program and non-program components differs extensively from conventional programs and therefore, is described in some detail here. As under the Core Protocol, evaluators administer survey questions to obtain participants’ rating of the importance of a comprehensive list of program and non-program factors on the decision to implement energy efficiency measures. Examples of Technical Assistance program factors that may be included are: Documentation in a program-provided technical report of the energy saving opportunities from installing the measure.
  - Verbal information or guidance provided by a program representative or energy auditor during a training course or an on-site visit.
  - A follow-up communication from the utility regarding implementing the recommendations provided through the audit, training or technical assistance.

Examples of Technical Assistance non-program factors that may be included are:

- Information from trade shows, conferences, or other professional gatherings
- Recommendation from an equipment vendor that sold you the measure and/or installed it
- Previous experience with the measure
- A recommendation from a design or consulting engineer
- Standard practice in your business/industry
- Corporate policy or guidelines
- Payback on the investment
4 Residential and Low Income Sector Protocols

The table below lists Illinois residential programs and the NTG protocol applicable to each program. If the design of a given program changes significantly, then it may mean that the NTG protocol listed for that program in this document is no longer appropriate. If that happens, the evaluator should follow the procedures outlined in Section 1.4: Diverging from the IL-NTG Methods.

<table>
<thead>
<tr>
<th>Program Administrator</th>
<th>Free Ridership Protocol</th>
<th>Program Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ameren Illinois</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.2 Appliance Recycling Protocol</td>
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<td>4.3 Residential Upstream Lighting Protocol</td>
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<tr>
<td>4.4 Prescriptive Rebate (With No Audit) Protocol</td>
<td>Heating and Cooling</td>
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<tr>
<td>4.5 Single-Family Home Energy Audit Protocol</td>
<td>All Electric Homes (Single Family)</td>
<td></td>
</tr>
<tr>
<td>4.6 Multifamily Protocol</td>
<td>All Electric Homes (Multifamily-Major Measures)</td>
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</tr>
<tr>
<td>4.7 Energy Saving Kits and Elementary Education Protocol</td>
<td>Multifamily (In-Unit, Common Area and Major Measures)</td>
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<tr>
<td>4.8 Residential New Construction Protocol</td>
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<td>5.1 Behavioral Protocol</td>
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42 The “Free Ridership Protocol Name” in the second column of the table refers to the numbered sections in this document, e.g., “4.6 Multifamily Protocol.”
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<thead>
<tr>
<th>Program Administrator</th>
<th>Free Ridership Protocol</th>
<th>Program Name</th>
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<td>Home Energy Reports (Opower)</td>
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<td>Power Smart Reports</td>
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<td>Shelton Solutions Great Energy Stewards</td>
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<td>Low-Income Kit Energy (LIKE)</td>
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<td>NTG=1†</td>
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<td>Weatherization Projects (Moderate Income, Deep Retrofit)</td>
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<td>4.5 Single-Family Home Energy Audit Protocol</td>
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<td></td>
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<td>Multifamily (Direct Install)</td>
</tr>
<tr>
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</tr>
<tr>
<td>All</td>
<td>5.2 Behavioral Protocol</td>
<td>Statewide Codes Collaborative</td>
</tr>
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</table>

† The Uniform Methods Project notes that “most low-income programs are not subject to NTG analysis (that is, are deemed at 1.0).” In line with that common practice, there is general consensus among Illinois stakeholders that the Illinois low-income programs should not be subject to NTG analysis and thus the NTG ratios for low-income programs are effectively deemed at 1.0. See Violetto and Rathbun (2014), Chapter 23: Estimating Net Savings: Common Practices. The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures, available electronically at http://www.nrel.gov/docs/fy14osti/62678.pdf, p. 50.

4.1 Residential Cross-Cutting Approaches

The approaches in this section can apply to more than one program type but do not supersede program-specific approaches presented in later sections.

4.1.1 Survey Design Issues

Free ridership questions should be asked near the beginning of a participant survey, before asking satisfaction questions. This should prevent participants from confusing free ridership questions with the satisfaction questions, which could influence free ridership scores.

4.1.2 Participant Spillover

Effective program marketing and outreach generates program participation and increases general energy efficiency awareness among customers. Spillover can be calculated using participant survey questions, which ask participants about energy-savings actions they have taken on their own since participating in the program. Questions should be sufficiently specific to ensure energy savings associated with spillover can be reasonably well-quantified. These may include questions about measure types or measures installed, quantities, and efficiency levels. When program implementers provide recommendations to participants and can provide data on the types of recommendations made to specific participants, evaluations should attempt to determine whether participants took the recommended actions outside of the program at sites within the program administrator’s service territory; if so, savings from those recommended actions should be attributed to the program.

To reduce the respondent’s burden, the survey should first ask participants about the influence the program had on their decision to take additional energy-saving actions on their own. In particular, the evaluation team should ask two close-ended questions to determine program influence on spillover actions. The two required questions, preceded by an optional open-ended warm-up question, are:

- OPTIONAL: Did the program influence you in any way to make these additional improvements?
1. How important was your participation in the <PROGRAM ADMINISTRATOR’S> program on your decision to make additional energy efficiency improvements on your own? [Scale from 0-10 where 0 is “not at all important” and 10 is “extremely important”]

2. If you had not participated in the <PROGRAM ADMINISTRATOR’S> program, how likely is it that you would still have implemented this measure, using a 0 to 10, scale where 0 means you definitely WOULD NOT have implemented this measure and 10 means you definitely WOULD have implemented this measure?

The response to the first required question cited above is “Measure Attribution Score 1,” and the response to the second required question cited above is “Measure Attribution Score 2.” The specific measures referenced in the question are considered to be attributable to the program if the “Spillover Score” is greater than 5.0:

\[ \text{Spillover Score} = \frac{(\text{Measure Attribution Score 1} + (10 - \text{Measure Attribution Score 2}))}{2} > 5.0 \]

If these conditions are met, the evaluator determines that the specific measures referenced in the question are attributable to the program; otherwise, the evaluator determines that the specific measures referenced in the question are not attributable to the program. The attribution criterion represents a threshold approach, in which energy impacts associated with measures implemented by program participants outside the program are either 100% program-attributable or 0% program-attributable.

For each measure mentioned, customers will be asked how they know the measure is more efficient than other models. If the respondent can identify the measure as ENERGY STAR or name an efficiency level that the evaluator confirms as being above the minimum federal standard, or if they identify a technology that the evaluator can confirm is above the minimum federal standard, it will count towards Participant Spillover.

Finally, depending on the measure type cited by the customer, follow-up questions should ask customers to provide reasonable information to allow the evaluator to estimate the amount of savings using IL-TRM protocols, such as quantity of appliances or the location and amount of insulation.

To calculate the spillover energy and demand savings for these actions, the appropriate version of the IL-TRM should be used. To develop the spillover rate, the total energy and demand impacts from the sampled participants who installed additional measures due to participation in the program are summed, and then this sum is divided by the total ex post sample energy and demand impacts:

\[ \text{Participant Spillover Rate (PSO)} = \frac{\text{Sum of Energy or Demand from Additional Measures Installed}}{\text{Sample Ex Post Gross Energy or Demand Impacts}} \]

The equation used to adjust the Core NTGR based on participant spillover is as follows:

\[ NTGR = (1 - FR + PSO) \]

4.1.2.1 Data Collection

Respondents should be drawn from a random sample of current or up to one year of previous program participants. Regardless of the participation year, spillover should be measured within the last 12 months (from the survey date), but after previous participation; the tracking database should supply this information.

4.1.2.2 Data Analysis

The following four steps calculate spillover:

1. Calculate total spillover savings for each participant installing an efficient measure not rebated through the program where the Spillover Score is greater than 5.0:

\[ \text{Measure Spillover} = \text{Measure Savings} \times \text{Number of Units} \]
2. Total savings associated with each program participant to calculate overall participant spillover savings.

3. Spillover Percentage Estimate = \frac{\sum \text{Sample Spillover kWh Savings}}{\text{Sample Evaluated Program kWh Savings}}

4.1.3 Nonparticipant Spillover Measured Through Trade Allies

In addition to participant free ridership and spillover, residential programs may create nonparticipant spillover (NPSO) through trade allies exposed to the program but not actually facilitating program participation. Rather, they promote and stock higher-efficiency equipment due to the program. NPSO caused by trade allies can be determined by surveying three groups of trade allies:

- Participating trade allies that do not submit rebates or otherwise act as program agents on behalf of their customers. For this group, care should be taken to ensure spillover is not double-counted with program sales.
- “Drop out” trade allies, who participated in the program previously but have not participated in the past 12 months.
- True nonparticipating trade allies that report they were aware of the program but had never participated.

Surveys ask nonparticipating trade allies if the program influenced their sales of high-efficiency equipment to nonparticipating customers and to quantify the program’s impact on their high-efficiency sales. The general questions take the following form:

- Q.1: How many <measures> did you sell in <period>?
- Q.2: How many of them were <efficiency level> or higher?
- Q.3: Had the <program> not existed, how many <measures> do you think you would have sold?

Evaluators should ensure that trade allies receive sufficient time to collect specific data and not rely on “guesses” to respond. Additional questions should be included to document how the program influenced sales of additional measures. Responses should also clarify whether sales counts are specific to the utility service territory in question.

The following steps calculate the program’s nonparticipant trade ally spillover percentage:

1. Compute the difference between the total reported number of high-efficiency units sold and the total that would have been sold in the program’s absence to obtain the total number of spillover units for that trade ally.
2. Multiply the total net number of spillover units of each measure sold by each surveyed trade ally by the average gross unit savings for each measure type.
3. Sum the result for each contractor from the previous step, and weight the results by the ratio of the population of non-active trade allies to the sample to compute the total spillover energy over the program period.
4. Divide the spillover energy savings by program gross savings.

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43 NPSO also can arise from nonparticipating customers as a direct result of general energy efficiency education and promotion efforts. A separate protocol addresses such NPSO. Care should be taken to ensure the different approaches do not double-count NPSO.
4.1.4 Nonparticipant Spillover Measured from Customers

The evaluation may perform research to measure nonparticipant spillover (NPSO). If so, care should be taken to ensure spillover is not double-counted with a trade-ally approach. The basic method uses a two-step process: (1) conduct a nonparticipant survey to identify potential spillover measures and (2) if needed, conduct a follow-up call or on-site visit by technical staff to confirm attribution and obtain information needed to estimate energy savings.

4.1.4.1 Basic Method

4.1.4.1.1 Sampling

As spillover may be rare in the nonparticipating population, determining spillover will likely require a large sample of customers who have not participated in any energy efficiency programs, including a behavioral program, within the past three years. Customers will be removed from the sample frame if their account numbers can be cross-referenced against a list of program participants from the previous three years. The survey should target household members responsible for paying utility bills. Survey respondents will be asked a screening question (whether they have participated in a program in the past three years) to confirm their household qualifies as a true nonparticipant.

4.1.4.1.2 Measure-Specific Questions

Depending on the spillover measure type reported by the customer, follow-up questions should be included to gather sufficient information to reasonably assess the saving amount by applying the IL-TRM, understanding that assumptions must be made if IL-TRM inputs cannot be easily supplied by the participant. Such assumptions should be conservative, or, if not conservative, reasons for deviating from the conservative application should be documented. Measures that cannot be reasonably quantified within available evaluation budgets should be excluded from spillover calculations.

For measures included in the IL-TRM, savings will be assessed using the IL-TRM algorithms. Baselines for measures not in the IL-TRM will be assessed based on appliance standards and building codes, if applicable, and, if not, through engineering judgements of existing or market conditions. Engineering assumptions and analysis by the evaluator will be applied for measures not included in the IL-TRM. Key assumptions should be documented in the report.

4.1.4.2 Attribution Approach

To receive credit for energy savings, the nonparticipant must fit the following criteria: (1) be familiar with the Program Administrators energy efficiency campaign (e.g., ActOnEnergy for Ameren); and (2) indicate that some aspect of the Program Administrator’s energy efficiency programs motivated their purchasing decisions. Influence will be measured on a scale of 0 to 10, where 10 is extremely influential and 0 is not at all influential. Savings attribution requires a Spillover Score of greater than 5.0.

Survey respondents will be asked a series of questions following the logic shown in Figure 4-1. First, the customer will indicate whether they know about their Program Administrator’s energy efficiency programs and/or marketing messages. If customer is aware, the survey will ask if they or anyone in their household made an energy efficiency improvement within the last year, and if so, what improvements they made. Responses to these questions will generate a list of potential spillover measures (shown at point “[A]” in Figure 4-1). Customers will be asked how they know the measure is more efficient than other models. If the respondent can identify the measure as ENERGY STAR or name an efficiency level that the evaluator confirms as being above the minimum federal standard, or if they identify a technology that the evaluator can confirm is above the minimum federal standard, it will count towards NPSO. At this point in the NPSO process, the customer could be referred for a follow-up call with a technical interviewer.

44 Customers who installed efficient lighting (CFL/LED) will not be eligible for NPSO if those savings are already...
To assess attribution for each spillover measure mentioned, the customer will be asked questions to be scored in two areas. Spillover may be program-attributable for those measures for which self-report data meet the following threshold condition:

\[ \text{Spillover Score} = \frac{(\text{Attribution Score 1} + (10 - \text{Attribution Score 2}))}{2} > 5.0 \]

### 4.1.4.2.1 Attribution Score 1

The first score, “Attribution Score 1,” measures the influence level (on a scale of 0 to 10, where 10 is extremely influential and 0 is not at all influential) their Program Administrator had on the decision to purchase the measure.

Influence can derive from the following:

1. General information about energy efficiency provided by the Program Administrator (e.g. through a bill insert)
2. Information from a contractor or retailer related to the Program Administrator’s programs.
3. Word-of-mouth from people installing energy-efficient equipment and receiving a rebate from the Program Administrator.

Attribution Score 1 is the maximum score (or Yes response) assigned to any source of influence from the Program Administrator.

### 4.1.4.2.2 Attribution Score 2

The second score, “Attribution Score 2,” comes from the customer’s response to a single question to assess the counterfactual, asking about the likelihood (on a scale of 0 to 10, where 10 is extremely likely and 0 is not at all likely) that the customer would have installed the measure had they not been influenced by the program.

The Spillover Score is then the average of the Attribution Score 1 and \((10 - \text{Attribution Score 2})\). If that Spillover Score is greater than 5.0, 100% of the savings are attributed to the Program Administrator for that measure.

Finally, depending on the measure type cited by the customer, follow-up questions will gather information to enable an estimate of savings (shown in the figure as \([B]\)), such as quantity of appliances or the location of insulation.

claimed by an upstream lighting program. A separate NPSO protocol is provided specifically for upstream lighting programs.
4.1.4.3 Scoring

Survey respondents’ answers to the NPSO questions will determine total energy and demand savings attributed to the program. Table 4-2 lists NPSO measures under column A, the Spillover Score under column B, the estimated measure savings under column C, the percentage of allocated savings under column D, and the total allocated savings under column E. Column F shows the calculated average energy savings per spillover measure, determined by dividing the total allocated savings (the sum of column E) by the number of surveyed nonparticipating customers. The table shows how kWh NPSO savings would be calculated; calculations of therm or demand savings would be accomplished in the same manner.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spillover Measure</td>
<td>Spillover Score</td>
<td>Measure Savings (kWh)</td>
<td>Allocated Savings</td>
<td>Total kWh Savings</td>
<td>Average kWh Per Surveyed Customer</td>
</tr>
<tr>
<td>Measure1</td>
<td>Scale of 0 to 10</td>
<td>Savings1</td>
<td>100% if [B] &gt; 5.0</td>
<td>[C] x [D]</td>
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<tr>
<td>Measure2</td>
<td>Scale of 0 to 10</td>
<td>Savings2</td>
<td>0% if [B] ≤ 5.0</td>
<td>[C] x [D]</td>
<td></td>
</tr>
<tr>
<td>MeasureN</td>
<td>Scale of 0 to 10</td>
<td>SavingsN</td>
<td></td>
<td>[C] x [D]</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Sum of column E = Total kWh Savings

Total kWh Savings ÷ Number of Completed Surveys

Table 4-3 shows the process for estimating total NPSO generated by the Program Administrator during the
program year (for electric savings). The savings attributed from the survey population will be extrapolated to the nonparticipating residential customer population to determine the overall NPSO savings. Then NPSO energy savings will be converted into a percentage using the total evaluated electric savings for the program year. A similar process would apply for calculating therm or demand NPSO.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source/Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>Average kWh Energy Savings per Surveyed Customer</td>
<td>Survey data and Savings Calculation</td>
</tr>
<tr>
<td>J</td>
<td>Total Nonparticipating Residential Population</td>
<td>Customer database</td>
</tr>
<tr>
<td>K</td>
<td>NPSO MWh Energy Savings Extrapolated to Nonparticipating Population</td>
<td>([F \times J] \div 1,000 \text{kWh/MWh})</td>
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<tr>
<td>S</td>
<td>Total Evaluated MWh Savings</td>
<td>Residential Portfolio Savings</td>
</tr>
<tr>
<td>G</td>
<td>NPSO Spillover Rate</td>
<td>(K \div S)</td>
</tr>
</tbody>
</table>

### Table 4-3. Calculation of Total NPSO Generated

#### 4.2 Appliance Recycling Protocol

Appliance recycling programs (ARPs) typically offer some mix of incentives and free pickups for the removal of old but operable refrigerators, freezers, or room air conditioners. These programs encourage consumers to undertake the following:

- Discontinue use of secondary or inefficient appliances;
- Relinquish appliances previously used as primary units upon their replacement (rather than keeping the old appliance as a secondary unit); and
- Prevent the continued use of old appliances in other households through direct transfers (i.e., giving it away or selling it) or indirect transfers (resale in the used appliance market).

As the program theory and logic for appliance recycling differ significantly from standard “downstream” incentive programs (which typically offer rebates for purchases of efficient products), the free ridership estimation approach also significantly differs.

The basic and enhanced methods are described next.

#### 4.2.1 Basic Method

##### 4.2.1.1 Free Ridership

Free ridership is based on participants’ anticipated plans had the program not been available, thus classifying a free rider as a participant who would have removed the unit from service regardless of the program.

Estimating net savings for ARPs should adopt a multistep process to segment participants into different groups, each with specific attributable savings.

In general, independent of program intervention, participating appliances would have been subject to one of the following options:

1. The appliance would have been kept by the participating household.
2. The appliance would have been discarded in a way that transfers the unit to another customer for continued use.
3. The appliance would have been discarded in a way that would have permanently removed the unit from service.
Only Option 3 constitutes free ridership (the proportion of units that would have been taken off the grid absent the program). Options 1 and 2 both indicate non-free riders. However, these respondents need to be further classified to account for potential induced replacement and secondary market impacts, both described below.

4.2.1.1.1 Data Collection

A participant survey—drawn from a random sample of participants—will serve as the primary source of data collected for estimating NTG for the ARP. To determine the percentage of participants in each of the three options, evaluators will begin by asking surveyed participants about the likely fate of their recycled appliance had it not been decommissioned through the program. Responses provided by participants generally can be categorized as follows:

1. Kept the appliance.
2. Sold the appliance to a private party (either an acquaintance or through a posted advertisement).
3. Sold or gave the appliance to a used-appliance dealer.
4. Gave the appliance to a private party, such as a friend or neighbor.
5. Gave the appliance to a charity organization, such as Goodwill Industries or a church.
6. Had the appliance removed by the dealer from whom the new or replacement appliance was obtained.
7. Hauled the appliance to a landfill or recycling center.
8. Hired someone else to haul the appliance away for junking, dumping, or recycling.

Additional, follow-up questions will be included to validate the viability of all responses.

Next, evaluators will assess whether each participant’s final response indicates free ridership:

- Some final responses clearly indicate free ridership, such as: “I would have taken it to the landfill or recycling center myself.”
- Other responses clearly indicate no free ridership, as when the appliance would have remained active within the participating home (“I would have kept it and continued to use it”) or used elsewhere within the Program Administrator’s service territory (“I would have given it to a family member, neighbor, or friend to use”).

If the respondent planned to have the unit picked up by the retailer and the retailer would likely resell the unit in the secondary market, they are not a free rider. Absent retailer survey primary research described in the Enhanced Options below, the evaluators will utilize data from the most recent research conducted of the ComEd program to determine the proportion of free riders unless another metric is mutually agreed upon by the evaluators. 45

Secondary Market Impacts

In the event that the unit would have been transferred to another household (Option 2 above), the question then becomes what purchasing decisions are made by the would-be acquirers of participating units now that these units are unavailable. Such would-be acquirers could:

1. Not purchase/acquire another unit.
2. Purchase/acquire another used unit.

Adjustments to savings based on these factors are referred to as the program’s secondary market impacts.

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45 Note that such retailer interviews are being conducted annually for the ComEd ARP evaluation, and answers are used directly in the calculation of the NTG ratio in cases where: (1) the respondent planned to have the unit picked up by the retailer; and (2) the retailer was interviewed.
If it is determined that the participant would have directly or indirectly (through a market actor) transferred the unit to another customer on the grid, the next question addresses what that potential acquirer did because that unit was unavailable. There are three possibilities:

- **A. None of the would-be acquirers would find another unit.** That is, program participation would result in a one-for-one reduction in the total number of appliances operating on the grid. In this case, the total energy consumption of avoided transfers (participating appliances that otherwise would have been used by another customer) should be credited as savings to the program. This position is consistent with the theory that participating appliances are essentially convenience goods for would-be acquirers. (That is, the potential acquirer would have accepted the appliance had it been readily available, but because the appliance was not a necessity, the potential acquirer would not seek out an alternate unit.)

- **B. All of the would-be acquirers would find another unit.** Thus, program participation has no effect on the total number of appliances operating on the grid. This position is consistent with the notion that participating appliances are necessities and that customers will always seek alternative units when participating appliances are unavailable.

- **C. Some of the would-be acquirers would find another unit, while others would not.** This possibility reflects the awareness that some acquirers were in the market for an appliance and would acquire another unit, while others were not (and would only have taken the unit opportunistically).

The evaluators will assume Possibility C unless primary research within a Program Administrator’s service territory to assess the secondary appliance market is undertaken as described in the Enhanced Options below. Specifically, evaluators will assume that half (0.5, the midpoint of Possibilities A and B) of the would-be acquirers of avoided transfers found an alternate unit.

Once the proportion of would-be acquirers who are assumed to find alternate units is determined, the next question is whether the alternate unit was likely to be another used appliance (similar to those recycled through the program) or, with fewer used appliances presumably available in the market due to program activity, would the customer acquire a new standard-efficiency unit instead.

### 4.2.1.2 Induced Replacement

If, however, the unit would have been kept by the participating household, the next question is whether the appliance was replaced and, if so, whether the household would have replaced the appliance regardless of the program.

The purchase of a refrigerator in conjunction with program participation does not necessarily indicate induced replacement. (The refrigerator market is continuously replacing older refrigerators with new units, independent of any programmatic effects.) However, if a customer would have not purchased the replacement unit (put another appliance on the grid) in the absence of the program, the net program savings should reflect this fact. This is, in effect, akin to negative spillover and will be used to adjust net program savings downward.

Estimating the proportion of households induced to replace their appliance should be done through participant surveys. As an example, participants could be asked, “Would you have purchased your replacement refrigerator if the recycling program had not been offered?”

Because an incentive ranging from $35 to $50 is unlikely to be sufficient motivation for purchasing an otherwise-unplanned replacement unit (which can cost $500 to $2,000), it is critical that evaluators include a follow-up question. That question should confirm the participants’ assertions that the program alone caused them to replace their refrigerator. For example, participants could be asked, “Let me be sure I understand correctly. Are you saying that you chose to purchase a new appliance because of the appliance recycling program, or are you saying that you would have purchased the new appliance regardless of the program?”

When assessing participant survey responses to calculate induced replacement, evaluators will consider the appliance recycled through the program as well as the participant’s stated intentions in the absence of the program. For example, if customers indicate they would have discarded their primary refrigerator independent of the program, it is not possible that the replacement was induced (because it is extremely unlikely the participant...
would live without a primary refrigerator). Induced replacement is a viable response for all other usage types and stated intention combinations.

As one might expect, previous evaluations have shown the number of induced replacements to be considerably smaller than the number of naturally occurring replacements unrelated to the program. Once the number of induced replacements is determined, this information is combined with the energy consumption replacement appliance to determine the total energy consumption induced by the program (on a per-unit basis).

4.2.1.3 Integrating Free Ridership, Secondary Market Impacts, and Induced Replacement

The flow chart shown in Figure 4-2 illustrates how net savings will be derived for an ARP. As shown, below, expected savings fall into four different scenarios.
Figure 4-2. Appliance Retirement Scenarios

4.2.1.4 Scoring Algorithm

Net savings will be assigned individually to each respondent, based on responses provided to the questions discussed above. Net savings will be averaged across all respondents to calculate program-level net savings. The following equation will be used:

\[ FR = (\text{free ridership and secondary market impacts} \% - \text{induced replacement} \%) \]

Table 4-4 demonstrates the proportion of a sample population classified into each of the eight potential (Tertiary Classification) categories and the resulting weighted net savings.

<table>
<thead>
<tr>
<th>Primary Classification</th>
<th>Secondary Classification</th>
<th>Tertiary Classification</th>
<th>Population (%)</th>
<th>UEC (kWh) w/out Program</th>
<th>UEC (kWh) w/ Program</th>
<th>kWh Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Would have kept unit</td>
<td>Scenario A: Kept but Induced Replacement</td>
<td>Non-ES unit</td>
<td>3%</td>
<td>1,026</td>
<td>520</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ES unit</td>
<td>2%</td>
<td>1,026</td>
<td>404</td>
<td>622</td>
</tr>
<tr>
<td>Would have removed unit</td>
<td>Scenario B: Kept but NO Induced Replacement</td>
<td>N/A</td>
<td>25%</td>
<td>1,026</td>
<td>0</td>
<td>1,026</td>
</tr>
<tr>
<td></td>
<td>Scenario C1: Transferred No Induced Replacement</td>
<td>N/A</td>
<td>30%</td>
<td>1,026</td>
<td>520</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>Scenario C2: Transferred With Induced Replacement</td>
<td>Non-ES unit</td>
<td>3.5%</td>
<td>1,026</td>
<td>520</td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>Scenario D: Removed from Service</td>
<td>Recycled/Destroyed</td>
<td>20%</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Retailer would Recycle</td>
<td>13%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

| Net Savings (kWh)       | 475 |

*The percent values presented in this table serve only as examples; actual research should be conducted to determine the percentage of units falling into each of these categories. Note that UEC (Unit Energy Consumption) values presented in the table represent example values, factoring in part-use.

4.2.2 Enhanced Method

Results can be enhanced by including three additional research efforts. The basic method has defaults where primary research on enhanced approaches cannot be performed:

1. A retailer survey, to determine the quantity and/or proportion of units returned to a retailer and that the retailer would deconstruct or recycle. Through this survey, one would determine a retailer’s criteria for reselling used units vs. deconstructing them, based on unit age and condition. Results from the survey and analysis would be used to determine the proportion of those who would have returned an old appliance
to the retailer that should be included in Scenario D (free riders). This research was conducted for ComEd in EPY6 evaluation and those results were applied to Ameren.

2. An appliance market assessment study to determine the size of the secondary appliance market and whether removal of participating units from the market would cause an otherwise would-be receiver to purchase an alternative used or new unit. Savings attributable to these participants are the most difficult to estimate, as the scenario attempts to estimate what the prospective buyer of a used appliance would do in the absence of finding a program-recycled unit in the marketplace (i.e., the program took the unit off the grid, so the prospective purchaser faced, in theory, a smaller supply of used appliances). It is difficult to answer this question with certainty, absent Program Administrator-specific information regarding the change in the total number of appliances (overall and used appliances specifically) that were active before and after program implementation. In some cases outside of Illinois, evaluators have conducted in-depth market research to estimate both the program’s impact on the secondary market and the appropriate attribution of savings for this scenario. Although these studies are imperfect, they can provide Program Administrator-specific information related to the program’s net energy impact. Where feasible, evaluators and utilities should design and implement such an approach. Unfortunately, this type of research tends to be cost-prohibitive, or the necessary data may simply be unavailable.

3. However, it is possible to estimate through nonparticipant surveys which of the disposal responses given by nonparticipants were most likely to have been to an opportunistic would-be-acquirer. Transfers that would most likely have been opportunistic are determined primarily based on the cost to the recipient. If the appliance was sold or transferred to a retailer, there would have been a cost to the recipient of that appliance. If the recipient was willing to pay for the appliance or was willing to exert the effort to visit a retail location, this suggests the recipient was actively seeking an appliance. However, if the unit were given away for free, there was little cost to the recipient and it is a reasonable proxy for the proportion of opportunistic acquirers. This proportion would replace the 50% default assumption (scenario C in Figure 4-2) of would-be-acquirers that would or would not find an alternate unit.

4. A nonparticipant survey can be used to assess how nonparticipants acquire and dispose of used units. As nonparticipants do not have the same perceived response bias as participants, they can help offset some of this potential bias in estimating the true proportion of the population that would have recycled their units in program’s absence. The evaluators will average the results of the nonparticipant survey with the participant survey if the nonparticipant survey is of sufficient sample size. Otherwise, results may be used for a qualitative characterization of potential bias. Though recommended, use of a nonparticipant survey need not be required, given budget and time considerations. A nonparticipant survey was completed as part of ComEd’s EPY6 evaluation and used qualitatively to validate participant results.

4.3 Residential Upstream Lighting Protocol

The Illinois Residential Upstream Lighting programs to date have provided discounts on efficient lighting through retailers at the point of purchase. Such programs often remain transparent to customers purchasing incentivized lighting. Program administrators also do not know the identity of most customers purchasing the program-discounted lighting; so these customers cannot easily be contacted once they leave the store for a traditional self-report NTG evaluation survey (i.e., an after-the-fact, direct solicitation of customers regarding what they would have done in the program’s absence). Similar surveys can be conducted with customers within program retailers after they have made their lighting purchasing decision but before they leave the store. For programs such as this, in store customer surveys are preferable to the traditional self-report telephone surveys that ask customers to recall their past light bulb purchases. Light bulbs are a small and relatively insignificant purchase for most people, thus the recall bias could be substantial.

Further, as upstream programs work with multiple market actors and can include wide-reaching marketing campaigns promoting energy efficiency to the general public, they tend to stimulate spillover and “market effects.” As a result, estimating NTG for upstream residential lighting programs can be challenging. Multiple methods exist, each with their own strengths and weaknesses.
Ameren and ComEd implement their residential lighting programs comparably, and the evaluation teams have used a consistent primary NTG evaluation method. This section details the consensus NTG methodology, which has been used multiple times for both ComEd and Ameren and is considered the most well-vetted and defensible NTG method that has been successfully used in Illinois.

For EPY5 and EPY6, Ameren and ComEd used a customer self-report methodology to estimate NTG for their upstream residential lighting programs. Customer self-report data in this method are collected during surveys conducted within program retailers with customers purchasing program bulbs (i.e., in-store intercept surveys). This method separately estimates free ridership, participant spillover, and nonparticipant spillover. Details follow on the primary data collection and scoring algorithms.

### 4.3.1 Basic Method

#### 4.3.1.1 Free Ridership

Free ridership for this program is calculated as the proportion of program bulbs that would have been purchased if the program did not exist. Three alternative scenarios could occur:

1. **Full Free Rider**: The customer would have purchased the same quantity of efficient bulbs (CFLs or LEDs) in the program’s absence.
2. **Partial Free Rider**: The customer would have purchased fewer efficient bulbs (CFLs or LEDs) in the program’s absence.
3. **Non-Free Rider**: The customer would have not purchased any efficient bulbs (CFLs or LEDs) in the program’s absence.

Free ridership is calculated as the average of two distinct scores: a Program Influence Score and a No-Program score. These scores are defined as follows:

1. **The Program Influence Score** captures the maximum level of program influence, reported by a survey respondent, of the residential lighting program on their decisions to purchase program bulbs on the day of the survey. This program influence can take a number of forms, such as: the monetary incentive provided to decrease the cost of high-efficiency bulbs; program-sponsored educational materials that explain the benefits of efficient lighting; in-store product placement of efficient bulbs; and program bulb recommendations provided by retail store personnel.

2. **The No-Program Score** is used to estimate how many program bulbs a survey respondent would have purchased in the absence of the residential lighting program.

Figure 4-3 illustrates the scoring algorithm for Residential Upstream Lighting Free Ridership via In-Store Intercepts.

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46 ComEd has used this method since EPY2. Ameren began using it in EPY5.
4.3.1.2 Data Collection

To estimate free ridership, the evaluation teams will conduct in-store intercept surveys with customers purchasing program-discounted lighting at participating retailers. Customers are asked questions that are used to estimate a Program Influence Score and a No-Program Score for each customer and efficient bulb type purchased.

**Primary Program Influence Score Questions**

1. Light bulb purchasing plans for current shopping trip (Yes/No)
2. If planning to purchase bulbs:
   a. Bulb type (CFL, LED, Incandescent, Halogen)
   b. Program administrator-incentivized bulbs (Yes/No)
3. Influence of various program factors:
   a. Program incentive
   b. In-store information (printed materials or information from Program Administrator representatives or retail personnel)
   c. Positioning of discounted bulbs within the store

**Primary No-Program Score Questions**

1. Stated preference of light bulb purchases had the Program Administrator incentive not been available (purchase all, some, or none of efficient bulbs)
2. Quantity of light bulbs purchased absent the incentive

4.3.1.3 Scoring Algorithms

Using the data collected from program participants during the in-store intercept surveys, Program Influence and No-Program Scores are calculated for each survey respondent and then combined to estimate a respondent-specific Free Ridership Score.

**4.3.1.3.1 Calculation of the Program Influence Score**

Survey respondents purchasing one or more program-discounted bulbs are assigned a Preliminary Program
Influence Score based on the maximum program influence level (on a 0 to 10 scale) they assigned to one or more program factors (e.g., monetary incentive/informational materials [printed or from store personnel]/product positioning). The influence level assigned to the monetary incentive should be increased for survey respondents (using a linear decreasing function) who indicated that, absent the incentive, they would not have purchased any of the program bulbs they were purchasing that day.

After the Preliminary Program Influence Score is assigned, a secondary algorithm is run that adjusts the preliminary program influence based on survey data regarding the customers purchasing plans when they entered the store. Survey respondents who indicated they planned to purchase high-efficiency bulbs prior to entering the store and who had not come to the store specifically to buy Program Administrator-incentivized program bulbs, should have their Program Influence Score cut in half. This adjustment makes the final Program Influence Score reflective of their stated planned intention to purchase efficient bulbs in the program’s absence.

4.3.1.3.2 Calculation of the No-Program Score

The No-Program Score is based on whether a respondent states they would have purchased all, some, or none of the program-discounted bulbs in the absence of Program Administrator incentives. Respondents reporting they would have purchased all of the efficient bulbs without the incentive should be considered free riders and receive a No-Program Score of zero. Those reporting they would have purchased none of the efficient bulbs without the incentives should be classified as non-free riders and receive a No-Program Score of 10, the maximum. Respondents reporting they would have purchased some of the efficient bulbs without the incentive should be assigned a No-Program Score between 0 and 10, reflective of the percentage of efficient bulbs they would not have purchased absent the program.

Respondents reporting they would have purchased all of the program-discounted bulbs in the program’s absence, but in-store materials provided by the Program Administrator had a moderate to high influence on their decision, should have their No-Program Scores adjusted to equal the level of influence they attributed to these program-sponsored informational materials.

4.3.1.4 Calculation of Free Ridership

The Free Ridership rate is calculated as follows:

\[
\text{Free Ridership} = 1 - \frac{(\text{Program Influence Score} + \text{No-Program Score})}{20}
\]

Using the calculated Program Influence and No-Program Scores, Free Ridership is calculated as one minus the sum of the two scores (Program Influence Score plus No-Program score), divided by 20. Dividing the sum of scores by 20 results in a ratio (between 0 and 1) that is representative of the average of the two zero to 10 scores. Subtracting this ratio from one reverses the score, thus representing the free ridership level. If either the No-Program or Program Influence Scores are missing, Free Ridership can be calculated using the single available score divided by 10. Evaluators may also reference available data to perform documented modifications to individual free ridership estimates resulting from the application of this free ridership assessment methodology.

4.3.2 Participant Spillover

For this program, participant spillover results from purchases of non-discounted efficient bulbs by program bulb purchasers who are influenced by their participation in the residential lighting program to purchase additional non-

\[\text{The function, adjusted monetary score } = \frac{\text{monetary score} + 10}{2}, \text{ increases the monetary score using a decreasing linear function. This function results in an increase in the monetary influence score of between 0 and 5 points depending on their original monetary score (i.e., an original score of 0 would become a 5, a 5 would become a 7.5, and a 10 would remain a 10). In past Illinois evaluations, this adjustment has typically changed less than 10% of all monetary scores.}\]
discounted efficient bulbs.

4.3.2.1 Data Collection

Data collected during in-store intercept surveys with customers purchasing program bulbs should be used to estimate participant spillover. During these surveys, customers purchasing program-discounted and non-discounted efficient bulbs (CFLs or LEDs) should be asked questions to determine whether the residential lighting program influenced their purchases of non-discounted efficient bulbs.

Primary Program Influence Score Question

1. Influence of the lighting program or in-store information on the customer’s decision to purchase non-discounted CFLs or LEDs. (0 to 10 scale where 0 is not at all influential and 10 is extremely influential)

4.3.2.2 Scoring Algorithm

To estimate participant spillover, the number of program-influenced, non-discounted efficient bulbs (CFLs or LEDs) purchased by program participants is divided by the total number of program bulbs purchased by these program participants. This results in the Participant Spillover Rate.

Step 1: Estimate the total number of non-discounted energy efficient bulbs purchased by respondents that had also purchased program-discounted bulbs and were influenced by the program. Respondents who gave a rating of greater than 5 on the program influence question are considered to be influenced by the program.

Figure 4-4 below provides a visual depiction of the process of qualifying non-discounted bulbs as participant spillover bulbs.

Step 2: Calculate the total number of program-discounted bulbs purchased by summing the number discounted
bulbs purchased by all respondents.

\textbf{Program Bulb Purchases} = \text{sum}(\text{Number of Discounted CFLs or LEDs purchased})

**Step 3:** Calculate the spillover rate by dividing the total number of spillover bulbs purchased by the total number of program-discounted bulbs purchased.

\textbf{Spillover Rate} = \frac{\text{Spillover Purchases}}{\text{Program Purchases}}

### 4.3.3 Nonparticipant Spillover

Nonparticipant spillover results from purchases of non-discounted efficient bulbs by customers who are not purchasing program-discounted bulbs, but report that the residential lighting program influenced their decision to purchase non-discounted efficient bulbs.

#### 4.3.3.1 Data Collection

Data collected during in-store intercept surveys with customers purchasing efficient bulbs not discounted by the program should be used to estimate nonparticipant spillover. During these surveys, customers purchasing non-discounted efficient bulbs (CFLs or LEDs) and not purchasing any program-discounted bulbs should be asked questions about awareness of the program discounts and point-of-purchase program marketing and educational materials. These questions are used to determine whether the residential lighting program influenced their purchases of non-discounted efficient bulbs.

**Primary Program Influence Score Question**

1. Influence of the lighting program or in-store information on the customer’s decision to purchase non-discounted CFLs or LEDs. (0 to 10 scale where 0 is not at all influential and 10 is extremely influential)

#### 4.3.3.2 Scoring Algorithm

The non-participant spillover scoring algorithm involves estimating the total number of non-participants, the incidence of non-participants in the sample, the total number of non-participant spillover bulbs, and the average number of non-participant spillover bulbs per customer in the sample, and then extrapolating the sample estimates to the population of the utility customers. Below are the steps used to calculate the non-participant spillover rate.

**Step 1.** Determine non-participant spillover in the sample by following the steps outlined below.

A. Determine the total number of non-participating customers in the survey sample:

\[ \text{Non-participating customers (survey)} = \text{customers who did not purchase any program-discounted energy efficient lighting products. These customers may have purchased non-discounted energy efficient lighting products, less efficient lighting products or both.} \]

B. Determine the incidence of non-participating customers in the survey sample by dividing non-participating customers by total customers in the sample:

\[ \text{Incidence of non-participating customers (survey)} = \frac{\text{Non-participating customers (survey)}}{\text{total customers (survey)}} \]

C. Determine total number of non-participant spillover bulbs by summing CFLs and LEDs not discounted by the program that were purchased by non-participating customers who were aware of the program discounts or marketing promoting energy efficient lighting and were influenced by it. Spillover qualifying bulbs are those purchased by customers who rate the program’s influence as greater than 5. The graphic below provides a visual depiction of the process of qualifying non-discounted products as spillover products.

Figure 4-5 below provides a visual depiction of the process of qualifying non-discounted bulbs as non-participant...
spillover bulbs.

**Figure 4-5. Residential Upstream Lighting Non-Participant Spillover Determination**

D. Determine the average number of non-participating spillover bulbs per non-participating customer by dividing the total number of non-participating spillover bulbs in the survey by the total number of non-participating customers in the survey.

\[
\text{Average number of non-participating spillover bulbs (survey)} = \frac{\text{total number of non-participating spillover bulbs (survey)}}{\text{non-participating customers (survey)}}
\]

Step 2. Extrapolate non-participant spillover to the population

A. Determine the total number of non-participating customers in the population by applying the non-participant incidence rate from the sample to the population

\[
\text{Total number of non-participating customers (population)} = \text{Utility residential customer count} \times \text{incidence of non-participating customers (survey)}
\]

B. Determine the total number of spillover bulbs by multiplying the average number of spillover bulbs per non-participating customer in the survey by the total estimate of non-participating customers

\[
\text{Total number of non-participant spillover bulbs} = \text{Average number of non-participant spillover bulbs (survey)} \times \text{total number of non-participating customers (population)}
\]

Step 3. Calculate non-participant spillover rate by dividing the total number of non-participant spillover bulbs in the population by the total number of program-discounted bulbs:
Non-participant spillover rate = \frac{\text{total number of non-participant spillover bulbs}}{\text{total number of program discounted bulbs}}

### 4.3.3.3 Method Advantages and Disadvantages

The in-store intercept method described above has certain advantages and disadvantages.

**Advantages:** This approach catches customers at their point of purchase, before they leave the store and can no longer be contacted directly. Given the interview’s timing, customers can more easily recall price factors leading to their purchase choices. Also, as customers are intercepted at the store rather than surveyed by telephone, a higher cooperation rate results.

**Disadvantages:** Customers may not fully connect the impact that in-store education, product placement, and advertising have on their decision making. While many consumers believe they are not influenced by advertising, retailers know advertising and product placement work. Further, store intercepts typically must be coordinated with education events, and many retailers do not allow interviews to take place in their stores. Consequently, results are not based on random samples of customers purchasing program-discounted lighting throughout the year and across all participating retailers, which could bias the results.

### 4.4 Prescriptive Rebate (With No Audit) Protocol

Prescriptive Rebate programs typically offer predetermined rebates to residential customers for purchasing measures such as high-efficiency furnaces, clothes washers, brushless/electronically commutated motors (ECMs), boilers, boiler reset controls, water heaters, air-source heat pumps (ASHPs), ground-source heat pumps (GSHPs), central air conditioners (CACs), programmable thermostats, smart thermostats, insulation, air sealing, duct sealing, and desktop power management software. The program may require installation by a registered program ally, but it does not require a home audit (although purchases may be made in response to an audit).

These programs encourage consumers to undertake the following:

- Purchase higher-efficiency equipment than they otherwise would have, had they shopped for such equipment at the same time (replace on burnout); and
- Replace operating but inefficient equipment with higher-efficiency equipment (early replacement).

The basic method for estimating free ridership and participant spillover (See Section 4.1.2) for these programs uses a participant self-report, based on a standard battery of questions. An enhanced method may utilize trade ally surveys to provide another quantitative assessment, which may be triangulated with the basic method approach. As discussed further in Section 4.4.2, trade ally surveys may also be used to assess nonparticipant spillover.

### 4.4.1 Basic Method

#### 4.4.1.1 Free Ridership

The free ridership assessment battery is brief to avoid applying an undue survey burden, yet it seeks to reduce self-report biases by including two main free ridership components:

- A Program Influence component, based on the participant’s perception of the program’s influence on the decision to carry out the energy-efficient project; and
- A No-Program component, based on the participant’s intention to carry out the energy-efficient project without program funds.

When scored, each component assesses the likelihood of free ridership on a scale of 0 to 10, with the two scores averaged and for a combined total free ridership score. As different and opposing biases potentially affect the two main components, the No-Program component typically indicates higher free ridership than the Program Influence...
component. Therefore, combining these decreases the biases.

Figure 4-6 illustrates the scoring algorithm.

**Figure 4-6. Residential Prescriptive Rebate (With No Audit) Free Ridership**

4.4.1.1 Calculation of the Program Influence Score

Program influence is assessed by asking respondents, on a scale from 0 (not at all important) to 10 (extremely important), how important they found various program elements were on their decision to undertake the project the way they did. The number of elements included will vary, depending on the program’s design. Logic models, program theory, and staff interviews typically inform the list of elements. Programs typically use the following elements to influence customer decision making: information; incentives or rebates; interaction with program staff (i.e., technical assistance); interaction with program proxies, such as members of a trade ally network; building audits or assessments; and financing.

In addition to asking about specific program influences, surveys ask respondents whether they planned to purchase a high-efficiency version of the product before learning of the rebate program. The respondent’s rating of the rebate’s influence is adjusted by 0.5 for those answering the question “yes.” Evaluators should conduct a sensitivity analysis around the use of this adjustment and present it in the report.

The Preliminary Program Influence Score equals the maximum influence rating for any program element rather than, for example, the mean influence rating. This is based on the rationale that if any given program element had a great influence on the respondent’s decision, then the program itself had a great influence, even if other elements had less influence.

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48 The Illinois NTG Working Group discussed using this question to check for consistencies rather than adjusting the score. The NTG working group agreed that it is preferable not to directly ask about conflicting language with residential customers and to utilize an open ended question instead to assess possible reasons for conflicting statements. It is the experience of the NTG working group members that residential customers tend to be more impatient with these types of questions and can typically respond easier to an open-ended question about their motivations.
An inverse relationship occurs between high program influence and free ridership: the greater the program influence, the lower the free ridership. The Program Influence (PI) Score = 10 - Preliminary Program Influence Score.

4.4.1.1.2 Calculation of the No-Program Score

The No-Program (NP) Score is based on three measures of the likelihood of a participant purchasing the exact same item(s) at the same time in the absence of the program. Each of these likelihood measures are assessed on a 0-10 scale in which 0 means not at all likely and 10 means very likely.

First, the participant should be asked their likelihood of purchasing an item of 
any efficiency within 12 or 6 months (12 months for a single or big ticket item and 6 months for less expensive items) for the Timing (T) Score. Participants who were influenced by the program to replace still-functioning equipment will likely give a low score to this question, while participants who needed to replace burned out equipment will give a high score. This measure enables the analysis to use a single algorithm for both early replacement and replace-on-burnout scenarios.

Next, the participant should be asked a key question that asks the respondent to gauge their likelihood of purchasing the exact same item (e.g., make, model, efficiency) had the program not existed. This measure forms the Efficiency (E) Score. A respondent stating the likelihood of purchasing the same exact item as a 5 on a scale of 0 to 10 is assigned an Efficiency Score of 5.

If multiple quantities of an item are purchased, the respondent should be asked about the likelihood of purchasing fewer energy-efficient items. The response to this question is subtracted from 10 to compute the Quantity (Q) Score.

The No-Program Score is the minimum of the Timing, Efficiency, and (if applicable) Quantity Scores. Finally, the No-Program Score is averaged with the Program Influence Score to calculate the Final Free Ridership Value.

\[
\text{No Program Score (NP)} = \min(T, E, Q)
\]

\[
\text{Free Ridership (FR)} = \text{Mean}(PI, NP)
\]

4.4.1.1.3 Consistency Checks

To address the possibility of conflicting responses (i.e., low intention score and high influence score), the survey should include consistency checks that, at a minimum, ask participants an open-ended question to address the program’s influence. For example:

- In your own words, please tell me the influence the program had on your decision to purchase the <insert measure name>.

In this case, the evaluation analyst will assess the response to this open ended question and its consistency with the other questions, and, if warranted based on clear additional information, they will adjust the score based on expert judgement. If an inconsistency exists and the open-ended response does not resolve the inconsistency, the respondent will be removed from the calculation. All instances of this occurring should be documented in the final report. Additional consistency checks, triggered and resolved within the survey with additional questions to participants, remain optional.

Missing responses to specific questions should be treated as “missing” for that particular question, but the observation or case will be retained in the analysis. Evaluation reports should note if this affects more than 5% of the responses.

4.4.2 Enhanced Method

4.4.2.1 Free Ridership

Free ridership results may be enhanced by including additional research efforts. A trade ally survey can be conducted to assess the percentage change in sales of high-efficiency equipment resulting from the program and the percentage of efficient equipment sales rebated through the program. Though these questions avoid directly asking for total sales before and after the program, the “with program” sales volume can be calculated by dividing
program tracking database counts of rebated products by the percentage of efficient products rebated through the program. The “without program” sales volume would then equal the “with program” sales volume, adjusted by the reported percentage change in equipment sales resulting from the program. Evaluators should ensure that trade allies receive sufficient time to collect specific data and not rely on “guesses” to respond. These results may be triangulated with participant survey results.

### 4.4.2.2 Triangulation

When multiple methods are used, evaluators may triangulate results by rating the analysis methodology and data collected using responses (rated on a scale of 0 to 10) to the following three questions:

1. All things being equal, on a scale of 0 to 10, with 0 being not at all likely and 10 being extremely likely, how likely is the approach to provide a more accurate estimate of free ridership?
2. Similarly, how valid is the data collected and the analysis performed (i.e., consider missing data, whether data collected was based on recollection or record keeping, is the analysis technique able to properly utilize the data collected)?
3. How representative is the sample (accounting for confidence and precision, and non-response or any sample frame bias)?

The weight for each method is the average score for that method divided by the sum of the average scores for all methods.

Table 4-5 illustrates example scoring for two different methods, illustrating the calculated weights.

<table>
<thead>
<tr>
<th>NTG Triangulation Data and Analysis</th>
<th>Method 1</th>
<th>Method 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. How likely is this approach to provide an accurate view of free ridership?</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2. How valid is the data collected/analysis?</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>3. How representative is the sample?</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Average Score</td>
<td>5.7</td>
<td>9</td>
</tr>
<tr>
<td>Sum of Averages</td>
<td>14.7</td>
<td>14.7</td>
</tr>
<tr>
<td>Weight</td>
<td>39%</td>
<td>61%</td>
</tr>
</tbody>
</table>

### 4.5 Single-Family Home Energy Audit Protocol

Single-Family Home Energy Audit programs (or energy assessment programs) seek to secure energy savings for residential customers by providing audits, direct-install measures, and incentives for additional energy efficiency opportunities. The participation process generally begins with an energy audit, performed by a program-affiliated companies or individuals; this involves an auditor assessing the customer’s home to identify energy-saving opportunities. At that time, the auditor may install free instant-savings measures, such as CFLs, low-flow showerheads, and faucet aerators. Auditors also may educate customers about incentives available through the audit program (e.g., air sealing, insulation) or other Program Administrator-sponsored energy efficiency programs.

For these programs, free ridership and participant spillover (See Section 4.1.2) estimates rely on participant self-reports, gathered through surveys.

#### 4.5.1 Basic Method

Given the multiple components of some audit programs, net impacts should be estimated using survey batteries tailored to a customer’s experience (e.g., receipt of free direct-install measures and discounted or rebated measures). The following sections outline the approach for two program components, one dealing with the direct
installation of free low-cost measures and a second dealing with envelope measures, such as air sealing and insulation.

4.5.1.1 No-Cost, Direct Install Measures

For free measures directly installed by program staff due to the audit, free ridership calculations should include the following components: Timing, Efficiency, and Quantity.

This approach provides several important benefits, such as deriving a partial free ridership score based on the likelihood that the participant would take similar actions in the absence of the audit. For example, partial scores can be assigned to customers who planned to install the measure, but the program influenced that decision, particularly in terms of timing (e.g., the program might have accelerated the installation) or quantity (e.g., the program might have led to installation of additional program-qualified measures).

Outlines of components and their associated survey questions follow:

- **Timing (T).** The first question is compute the Timing (T) Score accounts for earlier installation of measures due to the program by asking respondents about their likelihood (0-10 scale) to have installed an item of any efficiency within 6 or 12 months, had they not received it through the program (12 months for a single or big ticket item and 6 months for less expensive items).

- **Efficiency (E).** This score reflects the likelihood that customers would have installed the exact same energy-efficient measures, had the program not existed. For free measures, this is based on a question asking respondents to rate the likelihood that they would have installed the exact same measures had they not received them for free through the audit (on a 0 to 10 scale, where 0 is not at all likely and 10 is extremely likely). A higher likelihood value means a higher level of free ridership (i.e., a lower attribution level for the program).

- **Quantity (Q).** The question to compute the Quantity (Q) Score asks respondents about the likelihood that they would have installed fewer measures or performed less weatherization without the program. The response to this question is subtracted from 10 to compute the Quantity Score, as a lower score means a greater likelihood the respondent would have installed the same or a greater number of measures.

Given the low cost of the measures provided through the direct-install component of most audit programs and the number of measures received per participant, efforts have been made to streamline the free ridership battery to reduce the respondent’s burden. As such, the overall Final Free Ridership Value per measure can be calculated by taking the minimum of the Timing, Efficiency, and Quantity Scores, as shown in the following equation:

\[
Free\ Ridership\ (FR) = \text{Min}(T, E, Q)
\]

Figure 4-7 illustrates the algorithm for no-cost measures.
4.5.1.2 Rebated/Discounted Measures

Estimating NTG for rebated measures (typically for building shells) requires a more rigorous process than estimating NTG for free direct-install measures. In particular, the approach integrates an assessment of various program components that may have influenced the participant’s decision to install the measures. For discounted envelope measures, the basic free ridership factor consists of the following two components:

- A Program Influence component, based on the participant’s perception of the influence of various program elements—including the discount and the audit itself—on the decision to carry out the energy-efficient project; and
- A No-Program component, based on the participant’s likelihood of purchasing the exact same items at the same time in the absence of the program.

The free ridership method for discounted measures is identical to that used in the Prescriptive Rebate (With No Audit) protocol, with the one exception that the questions about program influence should be sure to include the audit itself as one of the program attributes. Evaluators should refer to Section 4.4.1.1 for details of the method. Figure 4-8 illustrates the algorithm for discounted measures.
4.5.1.3 Consistency Checks

To address the possibility of conflicting responses (e.g., the high likelihood to install the same measure in the program’s absence and the high importance of program factors), the survey should include consistency checks that, at a minimum, ask participants an open-ended question to address a program’s influence, such as the following:

- In your own words, please tell me the influence the program had on your decision to purchase the <insert measure name>.

For low or no-cost, direct-install measures, surveys should include two questions to assess a program’s influence on the respondent. The first should be asked at the beginning of the NTG battery, and the second should be asked at its conclusion. Questions include the following:

- Prior to the audit, had you purchased any <measures>? Y/N
- IF YES AND LIKELIHOOD TO INSTALL WITHOUT THE PROGRAM IS <7: Given that you had purchased <measures> before receiving the audit, why didn’t you purchase additional <measures> on your own without the program? [OPEN END]
- IF NO AND LIKELIHOOD TO INSTALL WITHOUT THE PROGRAM IS >6: Given that you have not purchased <measures> before, why were you likely to purchase <measures> on your own without the program? [OPEN END]

In both cases, the evaluation analyst will assess responses to open ended questions and their consistency with the other questions; if warranted, based on clear additional information, the evaluator will adjust the original question score if required. If inconsistency occurs and the open-ended response does not resolve it, the original question response will be removed from the calculation. Final reports should document all instances of such adjustments. Optionally, additional participant questions can be included to trigger and resolve additional consistency checks.

Missing responses to specific questions (e.g., don’t know or refused) should be treated as “missing” for those particular questions, but the analysis retains the observation or case. The evaluation reports should note if this affects more than 5% of responses.
4.6 Multifamily Protocol

Multifamily energy efficiency programs typically offer direct installation of low-cost, energy-efficient measures in multifamily dwelling units, in addition to rebates for common area lighting retrofits, air sealing, insulation, and improvements to HVAC systems and controls. These programs have various target audiences from owners, managers, or developers of market rate multifamily housing to those operating lower income or assisted living housing. Across these groups, properties must generally have a minimum of between three and five units to qualify for the programs.

Most multifamily program savings are typically achieved by encouraging customers to install higher-efficiency equipment than they would have installed on their own. However, programs may also encourage early replacement of still functioning equipment that is less efficient, thus impacting the timing of the installation, so that savings is realized earlier. The incentive may also make it more affordable for customers to install a greater number of high-efficiency measures.

The basic method for estimation of free ridership and participant spillover (See Section 4.1.2) for these types of programs is based on participant self-report gathered through surveys. For common area and building shell components of the program, participants are property managers and owners responsible for building maintenance and renovation. However, depending on the program design for the in-unit component of the program and specifically the installation of efficient lighting, the decision to participate in the program (i.e., install program measures) may arise from either property managers/owners or tenants or, potentially, both. This distinction is due to the fact that in some market-rate apartments, the tenant is responsible for decisions related to the installation of program measures, including light bulbs, while this is not common practice in income-qualified or assisted-living settings. For other in-unit measures, such as faucet aerators and low-flow showerheads, evaluators interview property managers/owners regarding program influence, as these measures are typically direct installed by program staff, and there is a limited likelihood of tenants making changes to these features.

To date, most programs have included CFLs as one of their measures; so the text in this section refers to CFLs. The protocol can also be applied when the program installs LEDs.

4.6.1 Basic Method

Estimating NTG for rebated measures requires a more rigorous process than estimating NTG for free direct-install measures. In particular, the approach integrates an assessment of various program components that may have influenced the participant’s decision to install the measures. For discounted measures, the basic free ridership factor consists of the following two components:

- A Program Influence component, based on the participant’s perception of the influence of various program elements—including the discount and the audit itself—on the decision to carry out the energy-efficient project; and
- A No-Program component, based on the participant’s likelihood of purchasing the exact same items at the same time in the absence of the program.

The free ridership method for discounted measures is identical to that used in the Prescriptive Rebate (With No Audit) protocol, with the one exception that the questions about program influence should be sure to include the audit itself as one of the program attributes. Evaluators should refer to Section 4.4.1.1.1 and 4.4.1.1.2 for details of the method. Figure 4-9 and Figure 4-10 also illustrate the algorithms for CFL and non-CFL measures.
4.6.1.1 Consistency Checks

To address the possibility of conflicting responses (e.g., high likelihood to install the same measure without the program, high importance to program factors), the survey should include consistency checks that, at a minimum, ask participants an open-ended question to address the program’s influence. For example:

- In your own words, please tell me the influence the program had on your decision to purchase the <insert measure name>.

The evaluation analyst will assess the responses to the open ended questions and their consistency with the other
survey questions, and, if warranted based on clear additional information, will adjust the original question score. If the open-ended response does not resolve the inconsistency, responses to the original question should be removed from the calculation. The survey may include additional consistency check triggers and resolutions through additional participant questions. The final report should document how often the consistency check rules were triggered, how often adjustments were made to scores, and how often inconsistencies could not be resolved.

Missing responses to specific questions (including don’t know or refused) should be treated as missing for that particular question, but the analysis should retain that observation or case. Evaluation reports should note if this affects more than 5% of the responses.

4.6.1.2 Data Collection

A participant survey should be used as the primary source of data collected for estimating free ridership in residential multifamily programs. As discussed, evaluators may field surveys with owners, property managers, or tenants, depending on a program’s design and theory. Determining the appropriate audience from which to gather information for estimating free ridership depends on the program’s design, and, ultimately, the party responsible for deciding to install specific program measures.

4.7 Energy Saving Kits and Elementary Education Protocol

Energy Saving Kits and Elementary Education Programs aim to secure energy savings through the distribution of kits containing various energy-saving measures, including (but not limited to): high-efficiency lighting (CFLs or LED lamps); bathroom and kitchen faucet aerators; and low-flow showerheads. Energy Saving Kits operate as an opt-in program; customers can request a kit by completing an Internet or phone application. Elementary Education Program participants do not request a kit as kits are distributed to all students in a classroom.

Free ridership and participant spillover (See Section 4.1.2) estimations for both programs rely upon participant self-report information gathered through surveys, despite the differences in distribution models. This methodology can be used for other energy-saving kit programs, including kits with alternative distribution methods (e.g., kits dropped off at a participant’s home).

The following section contains a description of the basic NTG method used. Figure 4-11 illustrates the method.
Free ridership calculations should include the following components: No-Program, Timing, and Quantity.

This approach provides several important benefits, such as the ability to derive a partial free ridership score based on the likelihood that similar actions would have taken place, even if the participant had not received a kit. For instance, partial scores can be assigned to customers with plans to install the measure, but the program at least influenced that decision, particularly in terms of timing (e.g., the program might have accelerated the installation) or quantity (e.g., the program might have led to the installation of additional measures).

Outlines of components and their associated survey questions follow:

- **Timing (T).** The first question is compute the Timing (T) Score accounts for earlier installation of measures due to the program by asking respondents about their likelihood (0-10 scale) to have installed an item of any efficiency within 6 or 12 months, had they not received it through the program (12 months for a single or big ticket item and 6 months for less expensive items).

- **Efficiency (E).** This score reflects the likelihood that customers would have installed the exact same energy-efficient measures, had the program not existed. This is based on a question asking respondents to rate the likelihood that they would have installed the exact same measures had they not received them for free through the kit (on a 0 to 10 scale, where 0 is not at all likely and 10 is extremely likely). A higher likelihood value means a higher level of free ridership (i.e., a lower attribution level for the program).

- **Quantity (Q).** The question to compute the Quantity (Q) Score asks respondents about the likelihood that they would have installed fewer measures without the program. The response to this question is subtracted from 10 to compute the Quantity Score, as a lower score means a greater likelihood the respondent would have installed the same or a greater number of measures.

Given the low cost of measures provided in the energy-saving kits as well as the number of measures included in each kit, efforts have been made to streamline the free ridership battery to reduce the respondent’s burden. As such, the overall Final Free Ridership Value per measure can be calculated by taking the minimum of the Timing, Efficiency, and Quantity Scores, as shown in the following equation:

\[
\text{Free Ridership (FR)} = \min(T, E, Q)
\]

Missing responses to specific questions (e.g., don’t know or refused) should be treated as “missing” for that particular question. Despite missing responses, the case will be retained in the analysis (pairwise deletion). The evaluation reports should present the percent missing for each of the three questions.
4.7.1.1 Data Collection

Evaluators should use a participant survey as the primary data collection source for estimating free ridership in Energy Saving Kits and Elementary Education Programs. As a general rule, a free ridership rate should be calculated for each separate kit component, and then be weighted by savings to determine the program-level results.

4.8 Residential New Construction Protocol

Residential New Construction programs typically offer builder training, technical information, marketing materials, and incentives to builders for the construction of eligible homes. Eligible homes must meet specific standards, designed to achieve energy efficiency levels above local building codes. Programs may use different tiers of standards to meet correspondingly different incentives.

The basic method for estimating free ridership and participant spillover for these programs is based on builder participant self-reporting, gathered through surveys.

The following section describes the basic method used.

4.8.1 Basic Method

For this program, a free rider is a builder who would have constructed a home at the program’s efficiency level in the program’s absence. Given the multiple methods available to achieve desired home energy efficiency levels, survey questions consider the builder’s likelihood of meeting the same energy efficiency standard, rather than whether or not the builder would have installed certain energy efficiency measures. Figure 4-12 (below) illustrates the method in more detail.

Evaluators assess Program Influence by asking respondents, on a scale from 0 (not at all important) to 10 (extremely important), how important they found various program elements in deciding to build to specific energy efficiency standards. The number of elements included vary, depending on the program’s design. Logic models, program theory, and staff interviews typically inform the list of program elements included. Programs typically use the following elements to influence builder decision making: marketing materials; incentives or rebates; contacts with HERS Raters; and technical assistance.

In addition to asking about specific program influences, surveys should ask builders whether they planned to build homes to the same standard before learning of the program.
4.8.1.1 Calculation of the Program Influence Score

The Program Influence Score (PI) equals 10 minus the maximum influence rating for any program element rather than, for example, the mean influence rating. This is based on the rationale that if any given program element had a great influence on the respondent’s decision, the program itself had a great influence, even if other elements had less influence.

4.8.1.2 Calculation of the No-Program Score

Evaluators calculate the No-Program score using a set of questions that ask respondents to gauge their likelihood of building homes to the same standards and in the same quantities had the program not existed. Three separate responses are considered in calculating the No-Program Score:

- The likelihood, on a scale of 0 to 10, that the builder would have built their homes to the same efficiency standard (Preliminary No-Program Score (NP₁))
  - If that likelihood is greater than 6, the likelihood of fewer homes being built to the same efficiency standard.
  - If that likelihood is greater than 6, the response to the question “for that scenario, what percentage of fewer homes would be built to the standard?” (Quantity Score = (100% - % answer) * 10, which will be a number between 0 and 10)

The resulting No-Program (NP) Score is calculated as follows:

\[ NP = \text{Mean}(NP₁, Q) \]

The overall Free Ridership Value derives from the average of the PI and NP scores, as shown in the following formula:
\[ FR = \text{Mean}(PI, NP) \]

4.8.1.2 Consistency Checks

To address the possibility of conflicting responses (e.g., the high likelihood to build to the same efficiency standards without the program, the high importance of program factors), the survey should include, at a minimum, consistency checks that ask participants an open-ended question to address the program’s influence. For example:

- In your own words, please tell me the influence the program had on your building practices.

If a high (>6) Preliminary Program Influence Score (PPIS) results, yet the builder planned to meet the same efficiency standard prior to learning of the program; or if the Preliminary Program Influence Score is lower (<7), and the builder did not plan to build to the standards prior to learning of the program, the survey should include a question to determine why this occurred, using wording that gets at the following inconsistencies:

- IF Preliminary Program Influence Score is >6 and Builder planned to meet the same efficiency standard prior to learning of THE PROGRAM: Given that you had plans to meet the standard prior to learning about the program, why do you think the <program elements> were influential in your decision to meet the standard? [OPEN END]
- IF Preliminary Program Influence Score is <7 and Builder had no plans to meet the same efficiency standard prior to learning of the program: Given that you had no plans to meet the standard prior to learning about the program, why do you think the <program elements> were not more influential in your decision to meet the standard? [OPEN END]

The evaluation analyst will assess the responses to the open ended questions and their consistency with the other survey questions, and, if warranted based on clear additional information, will adjust the original question score. If the open-ended response does not resolve the inconsistency, responses to the original question should be removed from the calculation. The survey may include additional consistency check triggers and resolutions through additional participant questions. The final report should document how often the consistency check rules were triggered, how often adjustments were made to scores, and how often inconsistencies could not be resolved.

Missing responses to specific questions (including don’t know or refused) should be treated as missing for that particular question, but the analysis should retain that observation or case. Evaluation reports should note if this affects more than 5% of the responses.

4.8.2 Participant Spillover

Participant spillover occurs when, due to program participation, a builder increases the energy efficiency of homes built outside the program (but inside a utility’s service territory) by adopting certain building practices used in participating homes. Participant spillover can be calculated based on participant builder survey questions that ask builders about homes built within the utility service territory but outside the program. Survey questions ask whether the builder increased the energy efficiency standards of non-program homes after participating in the program, and the number of homes they applied these increased standards to, within the utility’s service territory. Depending on the program characteristics, spillover should be measured as changes in specific building practices or as installation of specific measures. The text below assumes the program has been targeted at modifying building practices.

Spillover may be recorded depending on responses to the following questions:

1. How important was your experience in the <PROGRAM ADMINISTRATOR’S> program in your decision to incorporate this building practice your other homes, using a scale of 0 to 10, where 0 is not at all important and 10 is extremely important?

2. If you had not participated in the <PROGRAM ADMINISTRATOR’S> program, how likely is it that you would still have incorporated this building practice using a 0 to 10, scale where 0 means you definitely WOULD NOT have implemented this practice and 10 means you definitely WOULD have implemented this practice?
Responses to the first question establish the Practice Attribution Score 1, and responses to the second question establish the Practice Attribution Score 2. Spillover may be program-attributable for building practices with self-report data meeting the following condition:

\[ \text{Spillover Score} = \frac{(\text{Practice Attribution Score 1} + (10 - \text{Practice Attribution Score 2}))}{2} > 5.0 \]

For responses meeting these conditions, an evaluator determines that specific building practices referenced in the question are attributable to the program; otherwise, the evaluator determines that specific building practices referenced in the question are not attributable to the program. The attribution criteria represent a threshold approach, in which energy impacts associated with building practices program participants implement outside the program are either 100% program-attributable or 0% program-attributable.

For each building practice discussed, builders will be asked how they know the building practice is more efficient than other options. If the respondent can identify the building practice as ENERGY STAR or name an efficiency level that the evaluator confirms as above the minimum federal standard, or if they identify a technology that the evaluator can confirm is above the minimum federal standard, this counts towards participant spillover.

Finally, depending on the building practice cited by the builder, follow-up questions should ask customers to provide reasonable information to allow the evaluator to estimate the amount of savings using IL-TRM protocols, such as quantity of appliances or the location and amount of insulation.

To calculate the spillover energy and demand savings for these actions, further questions should be asked to assess the gross savings of the building practice, through the appropriate version of the IL-TRM, if available, and the number of homes to which it applied. To develop the Spillover Rate, the total energy and demand impacts from the sampled participants who implemented efficient building practices in other homes due to participation in the program is summed, and then this sum is divided by the total ex post sample energy and demand impacts:

\[ \text{Participant Spillover Rate (PSO)} = \frac{\text{Sum of Energy or Demand from Additional EE Practices}}{\text{Sample Ex Post Gross Energy or Demand Impacts}} \]

The equation used to adjust the Core NTGR based on participant spillover is as follows:

\[ \text{NTGR} = (1 - FR + PSO) \]

4.8.2.1 Sample

The sample for a spillover survey should be a random sample of current and up to one year previous program participants. Regardless of the year of participation, spillover should be measured within the set of homes that were completed within 12 months of the survey date.

4.8.3 Builder Nonparticipant Spillover

In addition to participant free ridership and spillover, new construction programs may create NPSO through builders exposed to the program but not actually participating. Rather, they implement some or all of the efficiency measures incorporated through the program in order to compete with builders that are participating. NPSO caused by builders can be determined by surveying two groups of builders:

- “Drop out” builders, who participated in the program previously but have not participated in the past 12 months.

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49 NPSO also can arise from nonparticipating customers as a direct result of general energy efficiency education and promotion efforts. A separate protocol addresses such NPSO. Care should be taken to ensure the different approaches do not double-count NPSO.
• True nonparticipating builders that report they were aware of the program or that other builders were taking steps to improve new home efficiency, but had never participated.

Surveys ask nonparticipating builders if their knowledge of other builders’ increased focus on energy efficiency influenced their building practices and in what manner, to quantify the program’s impact on nonparticipating homes. The survey questions will first identify specific building practices that go beyond the implemented energy code for the specific jurisdiction in which the builder is active. Table 4-6 lists the latest building energy code in place for most areas of Illinois. Evaluators should make efforts to ensure the building code under enforcement for each jurisdiction is used as the baseline when evaluating spillover savings.

<table>
<thead>
<tr>
<th>Table 4-6. IECC 2012 Building Energy Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Component</strong></td>
</tr>
<tr>
<td>Thermostat</td>
</tr>
<tr>
<td>Ceiling</td>
</tr>
<tr>
<td>Walls</td>
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<tr>
<td>Floors</td>
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<tr>
<td>Slab</td>
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<tr>
<td>Windows</td>
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<tr>
<td>Infiltration</td>
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<tr>
<td>Duct Leakage</td>
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<tr>
<td>Duct Insulation</td>
</tr>
<tr>
<td>Heat Pump</td>
</tr>
<tr>
<td>Furnace</td>
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<tr>
<td><strong>Component</strong></td>
</tr>
<tr>
<td>Boiler</td>
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<tr>
<td>AC</td>
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<tr>
<td>Lighting</td>
</tr>
<tr>
<td>Appliances</td>
</tr>
<tr>
<td>Gas Water Heat</td>
</tr>
<tr>
<td>Electric Water Heat</td>
</tr>
</tbody>
</table>

For each component that is more efficient than code, the following additional questions are asked:

1. How many homes did you sell in <period> that incorporated this upgrade?
2. Of these homes, how many would have incorporated this upgrade, had the <program> not existed?

Evaluators should ensure that nonparticipant builders receive sufficient time to collect specific data and not rely on “guesses” to respond. Responses should also clarify whether sales counts are specific to the utility service territory in question.

The following steps calculate the program’s nonparticipant builder spillover percentage:
1. Compute the difference between the total reported number of efficiency upgrades sold and the total that would have been sold in the program’s absence to obtain the total number of upgrades by type of upgrade for that builder.

2. Multiply the total net number of upgrades of each type sold by each surveyed builder by the average gross unit savings for each upgrade type.

3. Sum the result for each builder from the previous step, and weight the results by the ratio of the population of non-active builders to the sample to compute the total spillover energy over the program period.

4. Divide the spillover energy savings by program gross savings.

Should a general population survey be implemented for nonparticipant spillover, care should be taken to ensure spillover is not double-counted.
5 Cross-Sector Protocols

The following sections include protocols that may be applicable to programs in the residential as well as in the commercial, industrial, and public sectors. Table 3-1 Commercial, Industrial, and Public Sector Programs and Table 4-1 Residential and Low Income Programs present information regarding the applicability of these protocols to specific programs.

5.1 Behavioral Protocol

5.1.1 Randomized Controlled Trials

The SEE Action Network’s recent monograph on evaluating residential behavioral energy efficiency programs indicates most of these programs are designed as randomized controlled trials (RCTs). In this design, evaluators (and sometimes implementation contractors) randomly assign sampled members of a population of interest to treatment group or a control group. Among the benefits offered by an RCT—when properly applied—is that it eliminates most selection bias, including free ridership and participant spillover effects. Hence, producing net savings estimates. For some programs, evaluators must take a second step to calculate net savings to ensure savings are not being double-counted, either counting savings being claimed by other programs or savings already credited to earlier program efforts (often called “legacy uplift”). Only increases in participation in other programs should be considered in this uplift adjustment; changes to total savings do not need to be made based on decreases in participation in other programs.

Free ridership refers to participants in an energy efficiency program that would have saved energy even without the program’s stimulus. As these program participants would have engaged in energy-saving actions in the program’s absence, counting their savings exaggerates the program’s impact. RCTs eliminate free ridership bias because the random assignment of customers to treatment and control groups equally distributes such participants between the two. Upon comparing the two groups’ energy consumption, free ridership energy savings in the control group cancel out those in the treatment group, eliminating free ridership bias.

Participant spillover refers to the tendency of participants in an energy efficiency program to engage in additional energy-saving actions. Though these actions occur outside of the program’s scope, they also occur as a direct or indirect result of the program. The extent that these additional savings are not measured and attributed to the program by the evaluator understates the program’s impact.

Consideration of participant spillover effects begins by considering what participant spillover means in the context of behavior-based energy efficiency programs. As behavioral programs prescribe neither the installation of any specific measures or sets of measures nor the adoption of any particular behaviors, they likely would not cause


51 For example, most residential, behavior-based energy efficiency programs administered by Opower on behalf of energy utilities are designed as RCTs, as are some commercial and industrial behavioral programs: for example, the EnergyCheck program that Pulse Energy implements for Commonwealth Edison.

52 Small differences may occur between the distributions of free ridership’s propensity in the two groups for any given sample. Their expected values, however, will be identical, and in any case the size of any such discrepancies shrinks as sample size increases. Thus, this is only a potential concern for programs with unusually small numbers of participants.
participant spillover effects: energy savings resulting from a behavioral program’s influence would, by definition, be “in scope,” eliminating nearly all possibilities for participant spillover.

The only exceptions would be participant spillover effects not reflected on customers’ bills or meter data. These can arise if spillover savings occur in another venue—outside of the home (e.g., a workplace) for a residential behavioral program—or if the program’s design reduces energy consumption in one form (e.g., electricity) but results in spillover savings in another form (e.g., natural gas). To the extent that either situation occurs, an evaluation relying on an RCT would understate program savings.

In general, RCTs do not address nonparticipant spillover, which reflects a program’s influence on nonparticipants. Such spillover may arise from a behavioral energy efficiency program if, for example, the program indirectly influences customers in the control group or affects the availability of energy efficiency products and services to those served by the relevant market, regardless of whether they participate in the program or belong to the control group. Where significant nonparticipant spillover occurs, an evaluation relying on RCT would understate program savings.

In an RCT, energy consumption of the treatment and control groups can be appropriately compared through a regression analysis, using time-series observations on the usage of individual customers in the treatment and control groups during the pre- and post-treatment periods. Such data most commonly derive from customers’ monthly bill records, hence the frequent use of “billing analysis” to describe this approach (although higher-frequency usage data from customer AMI meters also can be used and provide some additional benefits). Due to the combined time-series/cross-section structure of such data sets, the NTG Working group recommends that panel regression techniques be used.

5.1.2 Non-Randomized Designs

Where randomized assignments prove infeasible, quasi-experimental evaluation methods can be substituted. These methods select a control group using nonrandom methods and are less reliable than RCTs, but, with appropriate care, they can produce valid results. Non-randomized designs can still produce net savings as their primary output, just as RCTs do.

Three quasi-experimental approaches are commonly used to evaluate behavior-based energy efficiency programs that cannot be construed as RCTs:

- Regression discontinuity (RD)
- Variation-in-adoption (VIA)
- Matched controls (MC).

All three create a nonrandom control group to replace a random control group used in the RCT approach.

**Regression Discontinuity.** RD requires basing a program’s eligibility on a continuous variable (e.g., customers’ adjusted gross income falling below a cutoff value for them to qualify for the program). When this is true, the RD

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53 These benefits include: having more observations per customer, which improves model precision; obviating concerns over billing periods with differing numbers of days; and providing the ability to observe intraday load shifting in addition to energy savings.

54 “Panel” refers to the data set consisting of time-series observations on energy consumption of a cross-section of treatment and control customers. Panel estimation techniques refer to the model’s inclusion of terms that control for individual customer heterogeneity (e.g., customer fixed effects or a lagged dependent variable), and cluster-robust standard errors, which can accommodate differing error variances across customers and an intracustomer correlation of errors.
method assumes customers just beyond the cutoff likely will be very similar, on average, to those just inside of it. The method compares changes in energy usage for a group just outside of the eligible range to that of a group of participants just on the other side of the eligibility cutoff. The RD approach, however, is susceptible to an important weakness: misspecification of the regression functional form.55

**Variation-in-Adoption.** The VIA model applies only to program participants.56 For this method, customers must sign up for the program on a rolling basis. VIA takes advantage of its enrollment’s differential timing to compare energy usage of customers opting in to that of customers not yet opting in (but doing so later). The method relies on an assumption that, in any given month, customers have already opted in; those that soon opt in have similar characteristics to those who have enrolled, both in observable and unobservable characteristics. For this assumption to prove valid, customers must decide to opt into the program at different times for essentially random reasons (e.g., influenced only by marketing exposure and program awareness).57 In particular, the decision to opt in should not relate to observable or unobservable household characteristics.58

**Matched Controls.** MC creates a control group by matching each treatment customer to the most similar nonparticipating customer available on the basis of exogenous covariates from the pre-enrollment period known to highly correlate with post-enrollment usage.59 The covariate most likely to correlate with post-enrollment energy usage in a given time period is customer energy usage during the same period of the preceding year, but other observable factors may be used when available. Implementing MC requires customer usage data for the year preceding all opt-in customers’ decisions to participate in the program, along with a large group of nonparticipants who can be assumed to be similar to opt-in customers, aside from their program participation status. The pool of potential matches should be drawn from the same customer class and rate category.

The MC method involves identifying a nonparticipating customer whose energy usage closely matches that of a program participant in the months preceding the participant’s enrollment in the program. The logic inherent in this approach is: if the analyst finds a set of nonparticipants who, on average, are the same as participants regarding energy consumption before program enrollment, these matches will provide a good counterfactual estimate of how much energy participants would have used in the program’s absence.

The MC approach does present a main weakness: it can only identify matches based on observable customer characteristics, which leaves open the exclusion of the possible influence of relevant unobservables. While factors other than pre-enrollment energy usage plausibly could be used (e.g., household income, demographics, etc.), other factors that may be correlated with behavior and other unobservable characteristics.

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57 This differs from an RCT with a recruit-and-delay design, in which customers do not choose when to opt in, but instead are randomly assigned different times to opt in, or from an RCT with a recruit-and-deny design, where customers are randomly denied access to the program.

58 As the validity of the VIA method depends on this assumption, it should be empirically tested to the extent possible. If program marketing is punctuated and dates of marketing exposure are known, it is possible to test whether household enrollment in any particular month is driven by marketing activity, as opposed to observed household characteristics or unobserved heterogeneity. A test of whether the energy usage of households before they opt in differs from households that opt in during any particular month as opposed to another month is built into the VIA regression model’s functional form. See Harding and Hsiaw, op. cit., for details.

geographic location) in the matching process to address relevant unobservable characteristics (e.g., attitudes toward energy conservation and environmental concerns), this assumption cannot be directly tested.\textsuperscript{60}

There is a special case of MC called propensity-score matching. This develops a binary choice model to predict the probability that a customer will opt into the program, and then, for a control group, chooses customers with a high propensity for opting in but choosing not to do so. This functions well if observable variables used to calculate the propensity score sufficiently correlate with relevant unobservables to explain differences between treatment and control customers that cannot be explained by matching observables. With most evaluations of energy efficiency programs, however, little (if any) data are available on customers other than their energy usage; so the distinction usually becomes irrelevant.

5.2 Code Compliance Protocol

The protocol represents a basic framework for estimating the NTGR that may be refined based on impact evaluation results. The NTGR is used to convert an estimate of gross savings into an estimate of net savings. Two general methods can be used to estimate gross energy impacts: (1) utility billing data analysis; and (2) building energy modeling.\textsuperscript{61} The specific method used depends on the availability of necessary data.

5.2.1 Data Collection

5.2.1.1 Program Documentation

To inform the NTGR estimate, the evaluator documents program delivery. Information collected includes the following: the number, location, and dates of training workshops; the topics covered; materials disseminated; the number of trainees in each workshop and the type of trainee; and the hours of instruction.

5.2.1.2 Stakeholder Interviews

To inform the NTGR estimate, the evaluator conducts interviews with key stakeholders involved in the program. Interviews should include training program managers, instructors, and trainees. Trainees typically include contractors, builders, consultants, code officials, and others involved in building design and construction. The interviews seek to gather information on how training affected building design, construction, new code compliance, and enforcement.

5.2.2 Attribution Assessment

The NTGR estimation method stays the same, regardless of the method used to estimate gross energy savings.

A Delphi panel\textsuperscript{62} produces an NTGR estimate that reflects the share of gross energy savings resulting from increased code compliance attributable to the program. Formed by selecting four to six knowledgeable professionals not associated with the program in any way,\textsuperscript{63} the panel receives estimates of gross energy savings,

\textsuperscript{60} Such secondary, observable characteristics are rarely available to evaluators of energy efficiency programs, except for geographic location (e.g., postal zone of customer premise).

\textsuperscript{61} The modeled energy savings approach is similar to the approach described by Department of Commerce in Exhibits 6.1 and 6.2 from excerpts of Docket 13-0499 through estimation of potential energy savings.


\textsuperscript{63} Delphi panelists should have no biases that would affect their assessment of the program’s effectiveness.
building construction data, and evidence of attribution—including the results of stakeholder interviews and program documentation. Panel members individually review the information and provide feedback regarding their NTGR estimates and rationales. Responses are compiled, with combined, anonymous responses circulated to all panel members. Panelists review this information, revise their initial estimates and rationales, as they deem appropriate, and provide new estimates and rationales. Evaluators review the second set of estimates and rationales to develop a final attribution estimate, accompanied with a summary of supporting rationales. This NTGR estimate, used in combination with the gross energy savings estimate and building construction data, produces a final estimate of net energy savings attributable to the program.

Selected individuals should be knowledgeable about building codes and all factors that could conceivably affect code compliance.
Appendix A: Overview of NTG Methods

The evaluation teams present information in this appendix to provide a relatively quick overview of NTG methods for readers unaccustomed to the possible methods that evaluators may deploy. It is not meant to be a complete or deep discussion about each of the methods presented. However, the evaluators in Illinois considered the inclusion of this appendix to be very important in acknowledging the current suite of methods deployed by evaluators throughout the U.S. and giving a framework for work within Illinois.

Much of the information shown below is taken directly from a single source—the national Uniform Methods Project, Chapter 23: Estimating Net Savings: Common Practices. (Violette and Rathbun, 2014) This document has done a nice job of summarizing the eight most common attribution methods currently in use across the U.S. The evaluation teams recommend that readers go first to this reference for further information. Additionally, while there are slightly over 100 references within the Violette and Rathbun document, other non-duplicative references are included where reasonable as additional resources for those interested in further research into any specific method.

6.1 Survey-Based Approaches

Virtually all Illinois based evaluations use a survey-based approach for programs where primary data is used to determine net savings. (The main exception is for behavioral programs which use statistical analysis based on a randomized control trial program design.) Survey-based approaches obtain data from program participants and nonparticipants using a structured data collection instrument implemented via phone, in person, or online. At times, evaluators create and use an unstructured depth-interview guide to collect information about attribution, and this provides both contextual data and quantitative data about a given project.

6.1.1 Self-Report Approach

The self-report approach relies on the abilities of customers to discuss the program influence as well as the somewhat abstract ideas of the counterfactual (i.e., what would have occurred absent the program) after making a choice to purchase an energy efficient item or take an energy efficient action unrelated to a purchase. For program participants, this could include doing nothing (i.e., leaving the existing equipment as-is), installing the same energy efficient equipment as they did through the program, or an intermediate step of installing equipment that is more efficient than what they had in place previously, but less efficient than what they installed through the program. Evaluators also use this approach when collecting information from trade allies or distributors. This self-report approach is not new, nor is it exclusively used by the energy efficiency industry. An important attribute of this approach is its reliance on well-designed and fielded survey questions; so that the data underlying subsequent analyses are accurate and complete.

The output of this approach is a NTG ratio which can be considered an index of the program’s influence on the decision to install energy-efficient equipment. The NTG ratio is applied to gross savings in order to obtain an estimate of net savings. The NTG ratio may include free ridership, spillover, or market effects, depending on the survey and analytical design. NTG ratios may be calculated at the measure, suite of measures, or program level and are typically average values weighted by savings. If sufficient information is available, analysis of NTG ratios among certain customer segments may be done to further inform changes to program design.

References

- Sudman, 1996
- Stone, et al., 2000
- Bradburn, et al., 2004
6.1.2 Econometric/Revealed Preference Approach

The econometric/revealed preference approach, while still considered a survey approach due to how data is collected, moves beyond asking people about the counterfactual and instead uses the observations of the evaluator to collect information for analysis of a NTG ratio. Within this approach, evaluators typically deploy similar sampling designs as for the self-report approach to collect data, but actively gather what a person is doing (i.e., what is being purchased in a store) to determine attribution.

6.2 Randomized Control Trials and Quasi-Experimental Designs

As mentioned earlier, evaluators deploy randomized control trials (RCT) for estimating savings from the behavioral programs within Illinois. Additionally, quasi-experimental designs (QED) have been used in the past in Illinois to estimate net savings from the upstream CFL program, and CFL, insulation, and air-sealing measures within the Home Performance with ENERGY STAR program.

RCT and QED use statistical analysis to determine regularities within the data that reveal net savings due to a program intervention. The analytical design attempts to control for factors that can confound net analysis. When estimating net savings within both an RCT and QED, two groups are included within the analysis: 1) a group that has been exposed to (i.e., treated by) a program; and 2) a group that has not been exposed to the program. Evaluators must carefully consider the choice of the non-exposed group (called a control group for RCTs or comparison group for QEDs).

RCT: This design must be integral to a program’s implementation. Without the ability to randomly assign customers to one group or another (or at least randomly encourage customers to participate in a program), the ability of the design to yield unambiguous estimates of net impacts is compromised. Evaluators often help design how a program is implemented and, if not involved at the outset, carefully review choices made by the implementation team.

QED: A QED may be designed after a program has been implemented. It relies on determination of an equivalent comparison group, which is often chosen based on energy use. QED is difficult to perform well within the commercial sector due to the heterogeneity of end uses within the sector.

The output of an RCT or QED equals the average net savings for the population within the statistical model. Evaluators may also analyze the data to help understand the savings within specific known segments if sufficient information and data points are available.

References

- Mohr, 1995
- Shadish, Cook, Campbell, 2002
- Scriven, 2008
- Donaldson, 2009

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64 Net savings are calculated when a comparison or control group of non-treated customers are part of the design. Statistical analyses can also obtain gross savings.

65 Economists strongly support this approach, but among program evaluators, the idea that an RCT is a “gold standard” for attribution research has been hotly debated for decades.
6.3 Deemed or Stipulated NTG Ratios

A deemed (or stipulated) NTG ratio is a value known prior to implementing a program and applied to estimate net savings for that program in a certain year.

Deemed or stipulated NTG ratios may be based on previous primary data collection, a review of secondary data, or agreed to among stakeholders. In Illinois, deemed or stipulated NTG ratios should reflect best estimates of likely future actual NTG ratios for the relevant program year, taking into consideration stakeholder input, the evaluator’s expertise, and the best and most up-to-date information.

6.4 Common Practice Baseline Approaches

For this method, the evaluation team estimates what a typical consumer would have done at the time of the project implementation. Essentially, what is “commonly done” becomes the basis for baseline energy consumption and calculation of net savings. No gross impacts are calculated in this approach. This baseline is defined as the counterfactual “i.e., what would have occurred absent the program” and has been referred to as current practice, common practice, or industry standard practice. Evaluators determine these practices through multiple methods, but often can be from self-report or on-site audits. The difference between the energy use of measures installed in the program and the energy use associated with current practice is considered by some to be sufficiently close to the net savings.

This approach is not in use in Illinois, but it is used elsewhere in the country, such as the Pacific Northwest and Delaware.

6.5 Market Analyses

Market analyses can be done in several ways. Market analyses are often used in theory-driven evaluations of market transformation programs.

Other non-sales data market analyses can be postulated on changes specified in program logic such as: 1) changes in the number of energy-efficient units manufactured; 2) changes in market actor behavior around promotion or stocking of energy-efficient items; or 3) reductions in prices. The analyses involving non-sales data must make a clear link between the program intervention and the changes found in the market. Additionally, outside of Illinois, while evaluators have extrapolated the market changes to specific energy or demand reductions, this activity may be viewed as tenuous due to assumptions that evaluators must make within the analysis.

Illinois is in a position to begin to discuss market analyses and how specific research may be able to interpret changes that have occurred (or may occur in the future) because of the program interventions over the past eight years. Market analyses can be backward looking through historical tracing, but it is best used when the logic of an intervention is described and specific market metrics are tracked over time.

6.6 Structured Expert Judgment Approaches

Closely tied to market analysis, this approach is a way for evaluators to gather credible evidence of changes that arise due to the intervention of a program. When deployed, it is often used as a cost-effective approach to estimate market effects or reach agreement on a NTG value when several different types of evidence are available. The key premise of this approach is the use of a select group of known experts that all stakeholders agree can provide unbiased information as well as having sufficient knowledge to judge what may have occurred absent a program intervention.

A Delphi Panel is an example of this approach where data are collected from two or more rounds of data collection (which can occur via e-mail, Internet, or in person). A round is when experts make their thoughts known about a specific subject; the evaluation team synthesizes the data and provides this collated data back to the group to discuss again. Allowing the full experts to see how their peers think about a topic helps to move the group towards consensus.
References

- Mosenthal, et al., 2000
- Powell, 2002

6.7 Program Theory-Driven Approach

This approach is not included in the Violette and Rathbun (2014) document as a high-level method, but it is discussed by the authors under the historical tracing method. The Illinois evaluators believe that it deserves at least a short discussion within this framework.

A program theory is the written narrative about why the activities of a program are expected to bring about change. Typically associated with this approach is the direct graphical explication of the linkages between activities, outputs, and outcomes through an impact logic model.66

A theory-driven evaluation denotes “[A]ny evaluation strategy or approach that explicitly integrates and uses stakeholder, social science, some combination of, or other types of theories in conceptualizing, designing, conducting, interpreting, and applying an evaluation.” (Coryn 2011) Within this approach, the ultimate conclusions regarding the efficacy of a program are based on the preponderance of the evidence and not on the results of any single analysis. Coryn and colleagues systematically examined 45 cases of theory-driven evaluations published over a 20-year period to ascertain how closely theory-driven evaluation practices comport with the key tenants of theory-driven evaluation as described and prescribed by prominent theoretical writers. One output from this analysis was the identification of the core principles and sub-principles of theory-driven evaluation. If interested, please review the reference under Coryn 2011.

As an approach, it is best used for complex programs and/or causal mechanisms that extend far into the future. Evaluators collect evidence that supports or rejects hypotheses that are explicit in the logic model. The case for program attribution is strengthened based on the extent to which an evaluation shows that the expected changes occur. Additionally, the evaluation team may be able to collect data that will answer questions about the longer-term outcomes of a program. This type of data collection may be very similar to market tracking activities described briefly above under Market Analyses.

This approach does not specifically estimate a NTG value, but Program Administrators can choose to keep, drop, or change a program based on intermediary data. Regulators must be convinced that the logic of a program is sound and that the intermediary outcomes are causally linked to expected savings.

References

- Weiss, 1997
- Chen, 2000
- Coryn, 2011

6.8 Case Studies Design

Case studies are used extensively in social sciences as well as many other disciplines or practice-oriented areas, such as political science, economics, education, and public policy. Case studies help to understand the how and why of a situation and typically retain a holistic aspect of real-life events. As such, they may be a useful approach to determine attribution. As with program theory design, though, the data collected and analyzed within a case

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66 Evaluators may use logic models to show program processes as well, but this is a program flow chart, not an impact model.
study approach will not typically yield a specific NTG value, but can provide credible evidence and insight that supports or refutes the changes brought about by program intervention.

To be used to assess attribution, evaluators must carefully design case studies to assure they account for the threats to causality (i.e., internal validity) that arise in any design. While not typically thought of in this manner, case study design can address multiple types of validity such as construct, internal, and external validity as well as assuring reliability. When establishing construct validity and reliability, evaluators must use multiple sources of evidence, create and maintain a study database, and maintain a “chain of evidence” within the analysis. Internal validity is shown through analytic tactics such as pattern matching, explanation building, addressing rival explanations, or using logic models. External validity centers on the ability to generalize the analytical findings to other similar situations. External validity may be shown through the replication of findings.

References

- Yin, 2003
- Stake, 2006
7 Appendix B: References


