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**VOLUME 4: CROSS-CUTTING MEASURES AND ATTACHMENTS**
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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: \( \geq 2.0 \) CADR/Watt (Dust)
- Standby Power Requirement: \( \leq 2.0 \) 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
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \text{kWh}_{\text{BASE}} - \text{kWh}_{\text{ESTAR}} \]

Where:
- \( \text{kWh}_{\text{BASE}} \) = Baseline kWh consumption per year\(^5\)
  - = see table below
- \( \text{kWh}_{\text{ESTAR}} \) = 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 Energy Consumption (kWh/year)</th>
<th>Unit Energy Consumption (kWh/year)</th>
<th>( \Delta \text{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

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

Where:
- \( \Delta \text{kWh} \) = 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 \text{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).

   \[
   \text{IMEFsavings}^{15} = \text{Capacity} \times (1/\text{IMEFbase} - 1/\text{IMEFeff}) \times Ncycles
   \]

   Where

   \( \text{Capacity} \) = Clothes Washer capacity (cubic feet)
   \( = \) Actual. If capacity is unknown assume 3.45 cubic feet\textsuperscript{16}
   \( \text{IMEFbase} \) = Integrated Modified Energy Factor of baseline unit
   \( = 1.66 \textsuperscript{17} \)
   \( \text{IMEFeff} \) = Integrated Modified Energy Factor of efficient unit
   \( = \) Actual. If unknown assume average values provided below.
   \( \text{Ncycles} \) = 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.
IMEFs savings 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

\[ \Delta \text{kWh} = [\text{Capacity} \times 1/\text{IMEFbase} \times \text{Ncycles} \times (\%\text{CWbase} + (\%\text{DHWbase} \times \%\text{Electric_DHW}) + (\%\text{Dryerbase} \times \%\text{Electric_Dryer}))] - [\text{Capacity} \times 1/\text{IMEFeff} \times \text{Ncycles} \times (\%\text{CWeff} + (\%\text{DHWeff} \times \%\text{Electric_DHW}) + (\%\text{Dryereff} \times \%\text{Electric_Dryer}))] \]

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)

| Percentage of Total Energy Consumption\(^{20}\) |
|----------------|----------------|----------------|
| %CW | %DHW | %Dryer |
| Baseline | 7.6% | 31.2% | 61.2% |
| ENERGY STAR | 8.1% | 23.4% | 68.5% |
| ENERGY STAR Most Efficient | 13.6% | 10% | 76.3% |

- \(\%\text{Electric_DHW}\) = 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>

- \(\%\text{Electric_Dryer}\) = 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.
<table>
<thead>
<tr>
<th>Dryer fuel</th>
<th>%Electric_Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>36%(^{22})</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>ΔkW</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>
<th>Unknown DHW Unknown Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR</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>
<td></td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</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>
<td></td>
</tr>
</tbody>
</table>

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

- \(\Delta kWh\) = Energy Savings as calculated above
- \(\text{Hours}\) = Assumed Run hours of Clothes Washer
  - 295 hours\(^{23}\)
- \(CF\) = Summer Peak Coincidence Factor for measure.
  - 0.038\(^{24}\)

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

<table>
<thead>
<tr>
<th>ΔkW</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>
<th>Unknown DHW Unknown Dryer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR</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>
<td></td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</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>
<td></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 1/I\text{MEFbase} \times N\text{cycles} \times ((%\text{DHWbase} \times %\text{Natural Gas DHW} \times R_{\text{eff}}) + (%\text{Dryerbase} \times %\text{Gas_Dryer}))) - (\text{Capacity} \times 1/I\text{MEFeff} \times N\text{cycles} \times ((%\text{DHWeff} \times %\text{Natural Gas DHW} \times R_{\text{eff}}) +

\(^{22}\) 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.

\(^{23}\) 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/)

\(^{24}\) Calculated from Itron eShapes, 8760 hourly data by end use for Missouri, as provided by Ameren.
\[(%\text{Dryereff} \times %\text{Gas_Dryer})\] * Therm_convert

Where:

| Therm_convert | = Conversion factor from kWh to Therm
| = 0.03413 |
| R_eff | = Recovery efficiency factor
| = 1.2625 |
| %\text{Natural Gas_DHW} | = Percentage of DHW savings assumed to be Natural Gas

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%\text{Natural Gas_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%26</td>
</tr>
</tbody>
</table>

| %\text{Gas_Dryer} | = Percentage of dryer savings assumed to be Natural Gas

<table>
<thead>
<tr>
<th>Dryer fuel</th>
<th>%\text{Gas_Dryer}</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>58%27</td>
</tr>
</tbody>
</table>

Other factors as defined above

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

<table>
<thead>
<tr>
<th>ΔTherms</th>
<th>Electric DHW</th>
<th>Gas DHW</th>
<th>Electric DHW</th>
<th>Gas DHW</th>
<th>Electric DHW</th>
<th>Gas DHW</th>
<th>Unknown DHW</th>
<th>Unknown DHW</th>
<th>Unknown DHW</th>
<th>Unknown DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY STAR</td>
<td>0.00</td>
<td>3.7</td>
<td>2.3</td>
<td>6.0</td>
<td>1.3</td>
<td>5.0</td>
<td>3.1</td>
<td>5.4</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>ENERGY STAR Most Efficient</td>
<td>0.00</td>
<td>6.6</td>
<td>3.1</td>
<td>9.8</td>
<td>1.8</td>
<td>8.4</td>
<td>5.6</td>
<td>8.7</td>
<td>7.4</td>
<td></td>
</tr>
</tbody>
</table>

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[\Delta \text{Water} \text{ (gallons)} = \text{Capacity} \times (IWFbase - IWFeff) \times Ncycles\]

Where

| IWFbase | = Integrated Water Factor of baseline clothes washer
| = 5.9228 |

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&lt;sup&gt;29&lt;/sup&gt;</th>
<th>ΔWater (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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<sup>29</sup> 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.\(^\text{30}\)

DEEMED MEASURE COST

The assumed incremental capital cost for this measure is $60.\(^\text{31}\)

LOADSHAPE

Loadshape R12 - Residential - Dehumidifier

---

\(^{30}\) 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**

\[ \Delta \text{kWh} = \frac{((\text{Avg Capacity} \times 0.473) / 24) \times \text{Hours}}{(1 / (\text{L/kWh}_{\text{Base}}) - 1 / (\text{L/kWh}_{\text{Eff}}))} \]

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</th>
<th>Capacity Used (pints/day)</th>
<th>Federal Standard Criteria (≥ L/kWh)</th>
<th>ENERGY STAR Criteria (≥ L/kWh)</th>
<th>Federal Standard</th>
<th>ENERGY STAR</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>(pints/day)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<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><em>Average</em>(^{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>Average</td>
<td>0.032</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

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35 Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator
36 Assume usage is evenly distributed day vs. night, weekday vs. weekend 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 Functionality</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 below:

<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 years.

**DEEMED MEASURE COST**

The incremental cost for this measure is $50.

---

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

\[ \Delta k\text{Wh}^{42} = (k\text{Wh}_\text{base} - k\text{Wh}_\text{ESTAR}) \times (\%k\text{Wh}_\text{op} + (\%k\text{Wh}_\text{heat} \times \%\text{Electric}_\text{DHW})) \]

Where:

- \(k\text{Wh}_\text{BASE}\) = Baseline kWh consumption per year

<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>

- \(k\text{Wh}_\text{ESTAR}\) = ENERGY STAR kWh annual consumption

<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>

- \(\%k\text{Wh}_\text{op}\) = Percentage of dishwasher energy consumption used for unit operation
  
  \[= 1 - 56\%^{43}\]
  
  = 44\%

- \(\%k\text{Wh}_\text{heat}\) = 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>DHW fuel</th>
<th>%\text{Electric}_\text{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

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

\(^{44}\) Ibid.
### 5.1.4 ENERGY STAR Dishwasher

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%Electric_DHW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>16%&lt;sup&gt;45&lt;/sup&gt;</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<sup>46</sup>

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

Where:

- **Hours** = Annual operating hours<sup>47</sup>
  - = 252 hours
- **CF** = Summer Peak Coincidence Factor
  - = 2.6%<sup>48</sup>

<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

\[
\Delta \text{Therm} = (kWh_{\text{base}} - kWh_{\text{ESTAR}}) \times \%\text{kWh}_\text{heat} \times \%\text{Natural Gas}_\text{DHW} \times R_{\text{eff}} \times 0.03413
\]

Where:

- **%kWh_heat** = % of dishwasher energy used for water heating
  - = 56%
- **%Natural Gas_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>

<sup>45</sup> 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.

<sup>46</sup> 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.

<sup>47</sup> 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/](http://205.254.135.7/consumption/residential/data/2009/)

<sup>48</sup> End use data from Ameren representing the average DW load during peak hours/peak load.
### 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:

#### Water Base

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Water Base (gallons) (^{51})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>840</td>
</tr>
<tr>
<td>Compact</td>
<td>588</td>
</tr>
</tbody>
</table>

#### Water EFF

<table>
<thead>
<tr>
<th>Dishwasher Type</th>
<th>Water EFF (gallons) (^{52})</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>( \Delta \text{Water} ) (gallons) (^{53})</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.


\(^{52}\) 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/](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 Max. Energy Use</td>
<td>ENERGY STAR Max. Energy Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in kWh/year</td>
<td>in kWh/year</td>
</tr>
<tr>
<td></td>
<td></td>
<td>54</td>
<td>55</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</td>
<td>7.75 or greater</td>
<td>9.88*AV+143.7</td>
<td>8.892*AV+129.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact Upright Freezers with Manual Defrost</td>
<td>&lt;7.75 and 36 inches</td>
<td>9.78*AV+250.8</td>
<td>7.824*AV+200.64</td>
</tr>
<tr>
<td></td>
<td>or less in height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact Upright Freezers with Automatic Defrost</td>
<td>&lt;7.75 and 36 inches</td>
<td>11.40*AV+391</td>
<td>9.12*AV+312.8</td>
</tr>
<tr>
<td></td>
<td>or less in height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compact Chest Freezers</td>
<td>&lt;7.75 and 36 inches</td>
<td>10.45*AV+152</td>
<td>8.36*AV+121.6</td>
</tr>
<tr>
<td></td>
<td>or less in height</td>
<td></td>
<td></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>

54 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
56 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43
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.\(^\text{58}\)

DEEMED MEASURE COST

The incremental cost for this measure is $35.\(^\text{59}\)

LOADSHAPE

Loadshape R04 - Residential Freezer

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 95%.\(^\text{60}\)

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS:

\[ \Delta \text{kWh} = \text{kWh}_{\text{base}} - \text{kWh}_{\text{ESTAR}} \]

Where:

\( \text{kWh}_{\text{base}} \) = Baseline kWh consumption per year as calculated in algorithm provided in table above.

\( \text{kWh}_{\text{ESTAR}} \) = 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:

\(^\text{58}\) Energy Star Freezer Calculator; [http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Freezer_Sav_Calc.xls?570a-f000](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Consumer_Residential_Freezer_Sav_Calc.xls?570a-f000)


\(^\text{60}\) Based on eShapes Residential Freezer load data as provided by Ameren.
### SUMMER COINCIDENT PEAK DEMAND SAVINGS

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

Where:

- \(\Delta kWh\) = Gross customer annual kWh savings for the measure
- \(\text{Hours}\) = 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:

\[
\Delta kW = 26.9/5890 \times 0.95
\]

\[= 0.0043 \text{ kW}\]

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 ft\(^3\) 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.
### Product Category

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Assumptions up to September 2014 kW Savings</th>
<th>Assumptions after September 2014 kW Savings</th>
</tr>
</thead>
<tbody>
<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></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>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>3. Refrigerator-Freezers--automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators--automatic defrost</td>
<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>
</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
67 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43

### Energy Star and CEE Tier 2 Refrigerator

#### Product Category

<table>
<thead>
<tr>
<th>Existing Unit</th>
<th>Assumptions up to September 2014</th>
<th>Assumptions after September 2014</th>
</tr>
</thead>
<tbody>
<tr>
<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><strong>without through-the-door ice service</strong></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>5A Refrigerator-freezer—automatic defrost with bottom-mounted freezer with through-the-door ice service</strong></td>
<td>10.20 AV + 356</td>
<td>8.16 AV + 284.8</td>
</tr>
<tr>
<td><strong>6. Refrigerator-Freezers—automatic defrost with top-mounted freezer with through-the-door ice service</strong></td>
<td>10.10 AV + 406</td>
<td>8.08 AV + 324.8</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 $\geq 20\%$ or $\geq 25\%$ 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.  
Remaining life of existing equipment is assumed to be 4 years.

**DEEMED MEASURE COST**

Time of Sale: The incremental cost for this measure is assumed to be $40 for an ENERGY STAR unit and $140 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.

The avoided replacement cost (after 4 years) of a baseline replacement refrigerator is $413. 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: \( \Delta k\text{Wh} = UEC_{\text{BASE}} - UEC_{\text{EE}} \)

Early Replacement:

\( \Delta k\text{Wh} \) for remaining life of existing unit (1st 4 years) = \( UEC_{\text{EXIST}} - UEC_{\text{EE}} \)

\( \Delta k\text{Wh} \) for remaining measure life (next 8 years) = \( UEC_{\text{BASE}} - UEC_{\text{EE}} \)

Where:

\( UEC_{\text{EXIST}} \) = Annual Unit Energy Consumption of existing unit as calculated in algorithm from 5.1.8 Refrigerator and Freezer Recycling measure.

\( UEC_{\text{BASE}} \) = Annual Unit Energy Consumption of baseline unit as calculated in algorithm provided in

68 From ENERGY STAR calculator:

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%.
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:

Assumptions prior to standard changes on September 1st, 2014:

<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;EE&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>475.7</td>
<td>380.5</td>
<td>356.8</td>
<td>647.2</td>
</tr>
<tr>
<td>2. Refrigerator-Freezer--partial automatic defrost</td>
<td>1027.7</td>
<td>475.7</td>
<td>380.5</td>
<td>356.8</td>
<td>647.2</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>396.4</td>
<td>391.7</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>475.5</td>
<td>733.7</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>433.2</td>
<td>352.5</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>464.1</td>
<td>319.5</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>499.7</td>
<td>707.9</td>
</tr>
</tbody>
</table>

Assumptions after standard changes on September 1<sup>st</sup>, 2014:

74 Volume is based on the ENERGY STAR calculator average assumption of 14.75 ft<sup>3</sup> fresh volume and 6.76 ft<sup>3</sup> freezer volume.

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<sup>3</sup> (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; 76</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

76 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.
= 1.25\textsuperscript{77} \\
LSAF = Load Shape Adjustment Factor \\
= 1.057 \textsuperscript{78}

If volume is unknown, use the following defaults:

<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 (1\textsuperscript{st} 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

\textsuperscript{77} Average temperature adjustment factor (to account for temperature conditions during peak period as compared to year as a whole) based on Blasnik, Michael, "Measurement and Verification of Residential Refrigerator Energy Use, Final Report, 2003-2004 Metering Study", July 29, 2004 (p. 47). It assumes 90 °F average outside temperature during peak period, 71°F average temperature in kitchens and 65°F average temperature in basement, and uses assumption that 66% of homes in Illinois have central cooling (CAC saturation: "Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009 from Energy Information Administration", 2009 Residential Energy Consumption Survey; http://www.eia.gov/consumption/residential/data/2009/xls/HC7.9%20Air%20Conditioning%20in%20Midwest%20Region.xls)

\textsuperscript{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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 8,000</td>
<td>11.0</td>
<td>10.0</td>
<td>11.5</td>
<td>10.5</td>
</tr>
<tr>
<td>8,000 to 10,999</td>
<td>10.9</td>
<td>9.6</td>
<td>11.4</td>
<td>10.1</td>
</tr>
<tr>
<td>11,000 to 13,999</td>
<td>10.9</td>
<td>9.5</td>
<td>11.4</td>
<td>10.0</td>
</tr>
<tr>
<td>14,000 to 19,999</td>
<td>10.7</td>
<td>9.3</td>
<td>11.2</td>
<td>9.7</td>
</tr>
<tr>
<td>20,000 to 24,999</td>
<td>9.4</td>
<td>9.4</td>
<td>9.8</td>
<td>9.8</td>
</tr>
<tr>
<td>&gt;= 25,000</td>
<td>9.0</td>
<td>9.4</td>
<td>9.4</td>
<td>9.8</td>
</tr>
<tr>
<td>With Reverse Cycle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 14,000</td>
<td>9.8</td>
<td>9.3</td>
<td>10.3</td>
<td>9.7</td>
</tr>
<tr>
<td>14,000 to 19,999</td>
<td>9.8</td>
<td>8.7</td>
<td>10.3</td>
<td>9.1</td>
</tr>
<tr>
<td>&gt;= 20,000</td>
<td>9.3</td>
<td>8.7</td>
<td>9.7</td>
<td>9.1</td>
</tr>
<tr>
<td>Casement-only</td>
<td>9.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Casement-Slider</td>
<td>10.4</td>
<td></td>
<td></td>
<td></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.

---

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: \(\Delta kWh = (FLH_{RoomAC} \times Btu/H \times (1/CEER_{base} - 1/CEER_{ree})) / 1000\)

Early Replacement:

\(\Delta kWh\) for remaining life of existing unit (1\(^{st}\) 4 years) = \(FLH_{RoomAC} \times Btu/H \times (1/EE{\text{Rexist/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%.

\(^{88}\) Consistent with coincidence factors found in: RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008

\[
\Delta \text{kWh for remaining measure life (next 8 years)} = \frac{\left( \text{FLH}_{\text{RoomAC}} \times \text{Btu/H} \times \left( \frac{1}{\text{CEER}_{\text{base}}} - \frac{1}{\text{CEER}_{\text{ee}}} \right) \right)}{1000}
\]

Where:

- \( \text{FLH}_{\text{RoomAC}} \): 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\(^{91}\)
- \( \text{EER}_{\text{exist}} \): 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)\(^{93}\)
- \( \text{CEER}_{\text{base}} \): Combined Energy Efficiency Ratio of baseline unit
  - As provided in tables above
- \( \text{CEER}_{\text{ee}} \): 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/Cac_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Cac_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’.
### SUMMER COINCIDENT PEAK DEMAND SAVINGS

**Time of Sale:**

For example for an 8,500 Btu/H capacity unit, with louvered sides, in an unknown location:

\[
\Delta k\text{Wh}_{\text{CEE TIER 1}} = \frac{(248 \times 8500 \times (1/10.9 - 1/11.4))}{1000} = 8.5 \text{kWh}
\]

**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:

\[
\Delta \text{kWh for remaining life of existing unit (1st 4 years)} = \frac{(319 \times 9000 \times (1/(7.7/1.01) - 1/11.4))}{1000} = 124.7 \text{kWh}
\]

\[
\Delta \text{kWh for remaining measure life (next 8 years)} = \frac{(319 \times 9000 \times (1/10.9 - 1/11.4))}{1000} = 11.6 \text{kWh}
\]

---

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:

\[ \Delta kW_{CEE \text{ TIER 1}} = \frac{(8500 \times (1/(10.9 \times 1.01) - 1/(11.4\times1.01))))}{1000} \times 0.3 \]

\[ = 0.010 \text{ kW} \]

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:

\[ \Delta kW \text{ for remaining life of existing unit (1st 4 years)} = \frac{(9000 \times (1/7.7 - 1/(11.4 \times 1.01))))}{1000} \times 0.3 \]

\[ = 0.12 \text{ kW} \]

\[ \Delta kW \text{ for remaining measure life (next 8 years)} = \frac{(9000 \times (1/(10.9 \times 1.01) - 1/(11.4 \times 1.01))))}{1000} \times 0.3 \]

\[ = 0.011 \text{ kW} \]

**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 $170\(^{97}\) 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>

\[
\Delta kWh = [83.32 + (\text{Age} \times 3.68) + (\text{Pre-1990} \times 485.04) + (\text{Size} \times 27.15) + (\text{Side-by-side} \times 406.78) + (\text{Proportion of Primary Appliances} \times 161.86) + (\text{CDD/365.25} \times \text{unconditioned} \times 15.37) + (\text{HDD/365.25} \times \text{unconditioned} \times -11.07)] \times \text{Part Use Factor}
\]

Where:

- \text{Age} = \text{Age of retired unit}
- \text{Pre-1990} = \text{Pre-1990 dummy (=1 if manufactured pre-1990, else 0)}
- \text{Size} = \text{Capacity (cubic feet) of retired unit}
- \text{Side-by-side} = \text{Side-by-side dummy (=1 if side-by-side, else 0)}
- \text{Primary Usage} = \text{Primary Usage Type (in absence of the program) dummy (=1 if Primary, else 0)}
- Interaction: Located in Unconditioned Space x CDD/365.25

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.

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”.
\( (=1 \times \text{CDD/365.25 if in unconditioned space}) \)

\[ \text{CDD} = \text{Cooling Degree Days} \]

\( = \text{Dependent on location}^{100}: \)

<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 \( \times \) HDD/365.25

\( (=1 \times \text{HDD/365.25 if in unconditioned space}) \)

\[ \text{HDD} = \text{Heating Degree Days} \]

\( = \text{Dependent on location}^{101}: \)

<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 \( = \text{To account for those units that are not running throughout the entire year. The most recent part-use factor participant survey results available at the start of the current program year shall be used}^{102}. \) For illustration purposes, this example uses 0.93.\(^{103}\)

For example, the program averages for AIC’s ARP in PY4 produce the following equation:

\[ \Delta \text{kWh} = [83.32 + (22.81 \times 3.68) + (0.45 \times 485.04) + (18.82 \times 27.15) + (0.17 \times 406.78) + (0.34 \times 161.86) + (1.29 \times 15.37) + (6.49 \times -11.07)] \times 0.93 \]

\[ = 969 \times 0.93 \]

\[ = 900.9 \text{ kWh} \]

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:\footnote{104}

<table>
<thead>
<tr>
<th>Independent Variable Description</th>
<th>Estimate Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>132.122</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>

\[\Delta kWh = [132.12 + (\text{Age} * 12.13) + (\text{Pre-1990} * 156.18) + (\text{Size} * 31.84) + (\text{Chest Freezer} * -19.71) + (\text{CDDs* unconditioned} * 9.78) + (\text{HDDs*unconditioned} * -12.75)] \times \text{Part Use Factor}\]

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
- Chest Freezer = Chest Freezer dummy (= 1 if chest freezer, else 0)
- Interaction: Located in Unconditioned Space x CDD/365.25
  
  (=1 * CDD/365.25 if in unconditioned space)

  CDD = Cooling Degree Days (see table above)

- Interaction: Located in Unconditioned Space x HDD/365.25
  
  (=1 * HDD/365.25 if in unconditioned space)

  HDD = Heating Degree Days (see table above)

- 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. For illustration purposes, the example uses 0.85.\footnote{106}

The program averages for AIC’s ARP PY4 program are used as an example.

\[\Delta kWh = [132.12 + (26.92 * 12.13) + (0.6 * 156.18) + (15.9 * 31.84) + (0.48 * -19.71) + (6.61 * 9.78) + (1.3 * -12.75)] \times 0.825\]

= 977 * 0.825

= 905 kWh

\textbf{SUMMER COINCIDENT PEAK DEMAND SAVINGS}

\[\Delta kW = \text{kWh/8766} \times \text{CF} \]
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**

\[ \Delta \text{kWh} = \left( FLH_{\text{RoomAC}} \times \frac{\text{Btu/hr} \times (1/\text{EER}_{\text{exist}})}{1000} \right) \]

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}

FLH_{\text{RoomAC}} = \text{dependent on location}\textsuperscript{110}:

<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\textsuperscript{111}</td>
<td>248</td>
</tr>
</tbody>
</table>

Btu/H = \text{Size of retired unit}

Btu/H = \text{Actual. If unknown assume 8500 Btu/hr}\textsuperscript{112}

EER_{\text{exist}} = \text{Efficiency of existing unit}

EER_{\text{exist}} = 7.7\textsuperscript{113}

For example for an 8500 Btu/h unit in Springfield:

$$\Delta kW = ((319 \times 8500 \times (1/7.7)) / 1000)$$

$$\Delta kW = 352 \text{kWh}$$

\textbf{SUMMER COINCIDENT PEAK DEMAND SAVINGS}

\[\Delta kW = \frac{(\text{Btu/hr} \times (1/\text{EER}_{\text{exist}}))/1000)}{\text{CF}}\]

Where:

\[\text{CF} = \text{Summer Peak Coincidence Factor for measure}\]

\[\text{CF} = 0.3\textsuperscript{114}\]

\textsuperscript{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) to FLH for Central Cooling for the same location (provided by AHRI: http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Cac_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.

\textsuperscript{111} Weighted based on number of residential occupied housing units in each zone.

\textsuperscript{112} Based on maximum capacity average from the RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008


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. 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.

DEEMED MEASURE COST

The incremental cost for an ENERGY STAR clothes dryer is assumed to be $152.

LOADSHAPE

N/A

COINCIDENCE FACTOR

The coincidence factor for this measure is 3.8%.

118 Based on coincidence factor of 3.8% for clothes washers
Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = (\text{Load/CEFbase} - \text{Load/CEFeff}) \times \text{Ncycles} \times \%\text{Electric} \]

Where:

Load = The average total weight (lbs) of clothes per drying cycle. If dryer size is unknown, assume standard.

\[
\begin{array}{|c|c|}
\hline
\text{Dryer Size} & \text{Load (lbs)}^{119} \\
\hline
\text{Standard} & 8.45 \\
\text{Compact} & 3 \\
\hline
\end{array}
\]

CEFbase = Combined energy factor (CEF) (lbs/kWh) of the baseline unit is based on existing federal standards energy factor and adjusted to CEF as performed in the ENERGY STAR analysis\(^{120}\). If product class unknown, assume electric, standard.

\[
\begin{array}{|c|c|}
\hline
\text{Product Class} & \text{CEF (lbs/kWh)} \\
\hline
\text{Vented Electric, Standard (≥ 4.4 ft}^3\text{)} & 3.11 \\
\text{Vented Electric, Compact (120V) (< 4.4 ft}^3\text{)} & 3.01 \\
\text{Vented Electric, Compact (240V) (<4.4 ft}^3\text{)} & 2.73 \\
\text{Ventless Electric, Compact (240V) (<4.4 ft}^3\text{)} & 2.13 \\
\text{Vented Gas} & 2.84^{121} \\
\hline
\end{array}
\]

CEFeff = CEF (lbs/kWh) of the ENERGY STAR unit based on ENERGY STAR requirements.\(^{122}\) If product class unknown, assume electric, standard.

\[
\begin{array}{|c|c|}
\hline
\text{Product Class} & \text{CEF (lbs/kWh)} \\
\hline
\text{Vented or Ventless Electric, Standard (≥ 4.4 ft}^3\text{)} & 3.93 \\
\text{Vented or Ventless Electric, Compact (120V) (< 4.4 ft}^3\text{)} & 3.80 \\
\text{Vented Electric, Compact (240V) (< 4.4 ft}^3\text{)} & 3.45 \\
\text{Ventless Electric, Compact (240V) (< 4.4 ft}^3\text{)} & 2.68 \\
\text{Vented Gas} & 3.48^{123} \\
\hline
\end{array}
\]

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. \url{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. \url{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:

\[
\Delta kWh = (8.45/3.11 - 8.45/3.93) \times 283 \times 100\% \\
= 160 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:
- \( \Delta kWh \) = Energy Savings as calculated above
- \( \text{Hours} \) = Annual run hours of clothes dryer. Use actual data if available. If unknown, use 283 hours per year.
- \( \text{CF} \) = 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.

\[
\Delta \text{Therm} = (\text{Load/EF}_{\text{base}} - \text{Load/CEF}_{\text{eff}}) \times N_{\text{cycles}} \times \text{Therm}_{\text{convert}} \times \%\text{Gas}
\]

Where:
- \( \text{Therm}_{\text{convert}} \) = Conversion factor from kWh to Therm
  = 0.03413
- \( \%\text{Gas} \) = 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:

\[ \Delta \text{Therm} = \left( \frac{8.45}{2.84} - \frac{8.45}{3.48} \right) \times 283 \times 0.03413 \times 0.84 \]

= 4.44 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**

\[
\Delta kWh = (kWh_{\text{base}} - kWh_{\text{ee}}) \times \text{Days}
\]

Where:

- \(kWh_{\text{base}}\) = Daily energy use (kWh/day) for baseline water cooler\(^{131}\)

<table>
<thead>
<tr>
<th>Type of Water Cooler</th>
<th>kWh(_{\text{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 Savings:

<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

= 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**

\[ ΔkW = \frac{ΔkWh}{Hours} \times CF \]

Where:

<table>
<thead>
<tr>
<th>Hours</th>
<th>Number of hours per year water cooler is in use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= 8766 hours&lt;sup&gt;134&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CF</th>
<th>Summer Peak Coincidence Factor for measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= 1.0</td>
</tr>
</tbody>
</table>

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\textsuperscript{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 $\text{10}\textsuperscript{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%\textsuperscript{137}.

\textsuperscript{135} This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2.

\textsuperscript{136} Price survey performed by Illume Advising LLC for IL TRM workpaper, see “Current Surge Protector Costs and Comparison 7-2016” spreadsheet.

\textsuperscript{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:

- \(\text{kWh}\) = Assumed annual kWh savings per unit
  - = 56.5 kWh for 5-plug units or 103 kWh for 7-plug units\(^{138}\)
- \(\text{ISR}\) = In Service Rate, dependent on delivery mechanism

<table>
<thead>
<tr>
<th>Delivery Mechanism</th>
<th>ISR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency Kit</td>
<td>69%</td>
</tr>
<tr>
<td>All other delivery mechanisms</td>
<td>100%</td>
</tr>
</tbody>
</table>

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(^{140})</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

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

Where:

- \(\text{Hours}\) = Annual number of hours during which the controlled standby loads are turned off by the Tier 1 Advanced power Strip.
  - = 7,129 \(^{141}\)

\(^{138}\) NYSERDA Measure Characterization for Advanced Power Strips. Study based on review of:
- Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.

\(^{139}\) Average of Ameren Missouri, Potomac Edison, and PPL Electric ISR for smart strips in kits.

\(^{140}\) Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips

\(^{141}\) Calculated as average of 5 and 7 plug savings assumptions.
\[ CF = \text{Summer Peak Coincidence Factor for measure} \]
\[ = 0.8^{142} \]

<table>
<thead>
<tr>
<th># Plugs</th>
<th>Delivery Mechanism</th>
<th>( \Delta kW )</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\(^{144}\). 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\(^{145}\).

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**

**Electric Energy Savings**

\[ \Delta \text{kWh} = \text{ERP} \times \text{BaselineEnergy}_{\text{AV}} \times \text{ISR} \]

Where:

\(^{146}\) 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.

\(^{147}\) 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\textsubscript{AV} = 432 kWh\textsuperscript{148}

<table>
<thead>
<tr>
<th>Product Class</th>
<th>Field trial ERP range</th>
<th>ERP used</th>
<th>BaselineEnergy\textsubscript{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**

\[ \Delta k\text{W} = \Delta k\text{Wh} / \text{Hours} \times \text{CF} \]

Where:

- \( \Delta k\text{Wh} \) = Energy savings as calculated above
- \( \text{Hours} \) = Annual number of hours during which the APS provides savings.
  
  \[ \text{Hours} = 4,380 \textsuperscript{149} \]
- \( \text{CF} \) = Summer Peak Coincidence Factor for measure
  
  \[ \text{CF} = 0.8 \textsuperscript{150} \]

**NATURAL GAS SAVINGS**

N/A\textsuperscript{151}

**WATER AND OTHER NON-ENERGY IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

\textsuperscript{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.

\textsuperscript{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.

\textsuperscript{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.

\textsuperscript{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)\(^{152}\).
   • 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.\(^{153}\)

   **Deemed Early Replacement Rates For ASHP**

<table>
<thead>
<tr>
<th>Early Replacement Rate for ASHP 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.

\(^{152}\) 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 1\textsuperscript{st} 2015; 14 SEER and 8.2HSPF.

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 (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.

\[
\begin{align*}
CF_{SSP, SF} &= \text{Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during utility peak hour)} \\
&= 72\%^{159} \\
CF_{PJM, SF} &= \text{PJM Summer Peak Coincidence Factor for Heat Pumps in single-family homes (average during PJM peak period)} \\
&= 46.6\%^{160} \\
CF_{SSP, MF} &= \text{Summer System Peak Coincidence Factor for Heat Pumps in multi-family homes (during system peak hour)} \\
&= 67\%^{161} \\
CF_{PJM, MF} &= \text{PJM Summer Peak Coincidence Factor for Heat Pumps in multi-family homes (average during peak period)} \\
&= 28.5\%
\end{align*}
\]

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

Time of sale:

\[
\Delta k\text{Wh} = \left( (FLH_{\text{cooling}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{base}} - 1/\text{SEER}_{\text{ee}})) / 1000 \right) + \left( (FLH_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{base}} - 1/\text{HSPF}_{\text{ee}})) / 1000 \right)
\]

Early replacement\textsuperscript{162}:

\[
\Delta k\text{WH for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance)}:
= \left( (FLH_{\text{cooling}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{exist}} - 1/\text{SEER}_{\text{ee}})) / 1000 \right) + \left( (FLH_{\text{heat}} \times
\]

\textsuperscript{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)’.
\textsuperscript{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.
\textsuperscript{161} Multifamily coincidence factors both from; All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems, Cadmus, October 2015
\textsuperscript{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).
\[
\text{Capacity_heating} \times \left( \frac{1}{\text{HSPF}\_\text{exist}} - \frac{1}{\text{HSPF}\_\text{ee}} \right) / 1000
\]

\[
\Delta \text{kWh for remaining measure life (next 12 years if replacing an ASHP)}:
\]

\[
= \left( \frac{\text{FLH}\_\text{cooling} \times \text{Capacity}\_\text{cooling} \times \left(\frac{1}{\text{SEER}\_\text{base}} - \frac{1}{\text{SEER}\_\text{ee}}\right)}{1000} \right) + \left( \frac{\text{FLH}\_\text{heat} \times \text{Capacity}\_\text{heating} \times \left(\frac{1}{\text{HSPF}\_\text{base}} - \frac{1}{\text{HSPF}\_\text{ee}}\right)}{1000} \right)
\]

Where:

- \( \text{FLH}\_\text{cooling} \) = Full load hours of air conditioning
- \( \text{SEER}\_\text{exist} \) = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)
  - Use actual SEER rating where it is possible to measure or reasonably estimate.

\[
\begin{array}{|c|c|c|c|}
\hline
\text{Climate Zone (City based upon)} & \text{FLH}\_\text{cooling (single family) }^{163} & \text{FLH}\_\text{cooling (general multi family) }^{164} & \text{FLH}\_\text{cooling (weatherized multi family) }^{165} \\
\hline
1 (Rockford) & 512 & 467 & 299 \\
2 (Chicago) & 570 & 506 & 324 \\
3 (Springfield) & 730 & 663 & 425 \\
4 (Belleville) & 1,035 & 940 & 603 \\
5 (Marion) & 903 & 820 & 526 \\
\text{Weighted Average}^{166} & 629 & 564 & 362 \\
\hline
\end{array}
\]

- \( \text{FLH}\_\text{cooling} \) is recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

- \( \text{FLH}\_\text{cooling} \) 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.

- \( \text{FLH}\_\text{cooling} \) is based on number of occupied residential housing units in each zone.

\[
\text{Capacity}\_\text{cooling} = \text{Cooling Capacity of Air Source Heat Pump (Btu/hr)}
\]

- \( \text{Actual (1 ton = 12,000Btu/hr)} \)

- \( \text{SEER}\_\text{exist} \) = Seasonal Energy Efficiency Ratio of existing cooling system (kBtu/kWh)

- \( \text{SEER}\_\text{base} \) = Seasonal Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/kWh)

- \( \text{SEER}\_\text{ee} \) = Seasonal Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/kWh)

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.

164 Ibid.

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 FLHcool where recalculated based on existing efficiencies consistent with the TRM rather than from the metering study.

166 Weighted based on number of occupied residential housing units in each zone.

167 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

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.

169 Based on Minimum Federal Standard effective 1/1/2015;
= 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 = 12,000 Btu/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

HSFP_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.

= Actual

### 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:

\[
\Delta kWh = \left( \frac{903 \times 36,000 \times (1/14 - 1/15)}{1000} \right) + \left( \frac{1,288 \times 36,000 \times (1/8.2 - 1/9)}{1000} \right)
\]

\[
= 657 \text{ kWh}
\]

### 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:

\[
\Delta kW \text{ for remaining life of existing unit (1st 6 years):}
\]

\[
= \left( \frac{903 \times 36,000 \times (1/9.12 - 1/15)}{1000} \right) + \left( \frac{1,288 \times 36,000 \times (1/5.44 - 1/9)}{1000} \right)
\]

\[
= 4769 \text{ kWh}
\]

\[
\Delta kW \text{ for remaining measure life (next 12 years):}
\]

\[
= \left( \frac{903 \times 36,000 \times (1/14 - 1/15)}{1000} \right) + \left( \frac{1,288 \times 36,000 \times (1/8.2 - 1/9)}{1000} \right)
\]

\[
= 657 \text{ kWh}
\]

---

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

### Time of sale:

\[
\Delta kW = \left( \frac{\text{Capacity}_{\text{cooling}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}})}{1000} \right) \times \text{CF}
\]

### Early replacement\(^{177}\):

\[
\Delta kW \text{ for remaining life of existing unit (1st 6 years for replacing an ASHP, 18 years for replacing electric resistance):}
\]

\[
= \left( \frac{\text{Capacity}_{\text{cooling}} \times (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{ee}})}{1000} \right) \times \text{CF};
\]

\[
\Delta kW \text{ for remaining measure life (next 12 years if replacing an ASHP):}
\]

\[
= \left( \frac{\text{Capacity}_{\text{cooling}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}})}{1000} \right) \times \text{CF}
\]

Where:

\[
\text{EER}_{\text{exist}} = \text{Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)}
\]

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

\[
\text{EER}_{\text{base}} = (-0.02 \times \text{SEER}_{\text{exist}}^2) + (1.12 \times \text{SEER}_{\text{exist}}) \quad \text{178}
\]

If SEER or EER rating unavailable use:

---

\(^{177}\) 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).

Existing Cooling System | EER_exist
--- | ---
Air Source Heat Pump | 8.55
Central AC | 8.15
No central cooling | Make ‘1/EER_exist’ = 0

EER_base = Energy Efficiency Ratio of baseline Air Source Heat Pump (kBtu/hr / kW)
= 11.8

EER_ee = Energy Efficiency Ratio of efficient Air Source Heat Pump (kBtu/hr / kW)
= Actual, if not provided convert SEER to EER using this formula:
= \((-0.02 \times SEER_{ee}^2) + (1.12 \times SEER_{ee})\)

CF_{SSP, SF} = Summer System Peak Coincidence Factor for Heat Pumps in single-family homes (during system peak hour)
= 72% \(^{183}\)

CF_{PJM, SF} = PJM Summer Peak Coincidence Factor for Heat Pumps in single-family homes (average during peak period)
= 46.6% \(^{184}\)

CF_{SSP, MF} = Summer System Peak Coincidence Factor for Heat Pumps in multi-family homes (during system peak hour)
= 67% \(^{185}\)

CF_{PJM, MF} = PJM Summer Peak Coincidence Factor for Heat Pumps in multi-family homes (average during peak period)
= 28.5% \(^{35}\)

\(^{179}\) 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: \((-0.02 \times SEER2) + (1.12 \times SEER)\)


\(^{183}\) 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
Time of Sale:
For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump installed in single-family home in Marion:

\[
\Delta kW_{SSP} = \left(\frac{36,000 \times (1/11.8 - 1/12)}{1000}\right) \times 0.72 = 0.037 \text{ kW} \\
\Delta kW_{PJM} = \left(\frac{36,000 \times (1/11.8 - 1/12)}{1000}\right) \times 0.466 = 0.024 \text{ kW}
\]

Early Replacement:
For example, a three ton, 15 SEER, 12EER, 9 HSPF Air Source Heat Pump replaces an existing working Air Source Heat Pump with unknown efficiency ratings in single-family home in Marion:

\[
\Delta kW_{SSP} \text{ for remaining life of existing unit (1st 6 years):} \\
= \left(\frac{36,000 \times (1/8.55 - 1/12)}{1000}\right) \times 0.72 = 0.872 \text{ kW} \\
\Delta kW_{SSP} \text{ for remaining measure life (next 12 years):} \\
= \left(\frac{36,000 \times (1/11.8 - 1/12)}{1000}\right) \times 0.72 = 0.037 \text{ kW} \\
\Delta kW_{PJM} \text{ for remaining life of existing unit (1st 6 years):} \\
= \left(\frac{36,000 \times (1/8.55 - 1/12)}{1000}\right) \times 0.466 = 0.564 \text{ kW} \\
\Delta kW_{PJM} \text{ for remaining measure life (next 12 years):} \\
= \left(\frac{36,000 \times (1/11.8 - 1/12)}{1000}\right) \times 0.466 = 0.024 \text{ kW}
\]

**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**

\[ \Delta \text{Therm} = \left( \frac{1}{R_{\text{exist}}} * C_{\text{exist}} \right) - \left( \frac{1}{R_{\text{new}}} * C_{\text{new}} \right) \right) * FLH_{\text{heat}} * L * \Delta T / \eta_{\text{Boiler}} / 100,000 \]

Where:

\[ R_{\text{exist}} \]
Pipe heat loss coefficient of uninsulated pipe (existing) \([(\text{hr}-\text{°F} - \text{ft}^2)/\text{Btu}]\)

---


\(^{187}\) Consistent with DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com).
R_{new} = \text{Pipe heat loss coefficient of insulated pipe (new)} \left[ (\text{hr} \cdot ^\circ\text{F} \cdot \text{ft}^2)/\text{Btu} \right] = \text{Actual} \left(0.5 + \text{R value of insulation}\right)

FLH_{heat} = \text{Full load hours of heating} = \text{Dependent on location}^{189}: 

\begin{center}
\begin{tabular}{|c|c|}
\hline
Climate Zone (City based upon) & FLH_{heat} \\
\hline
1 (Rockford) & 1,969 \\
2 (Chicago) & 1,840 \\
3 (Springfield) & 1,754 \\
4 (Belleville) & 1,266 \\
5 (Marion) & 1,288 \\
Weighted Average\textsuperscript{190} & 1,821 \\
\hline
\end{tabular}
\end{center}

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)} \left(\text{Diameter (in)} \times \pi/12\right) = \text{Actual} \left(0.5'' \text{ pipe} = 0.131\text{ft, 0.75'' pipe} = 0.196\text{ft}\right)

C_{\text{new}} = \text{Circumference of pipe with insulation (ft)} \left(\left(\text{Diameter of pipe (in)}\right) + \left(\text{Thickness of Insulation (in)}\right)^2\right) \times \pi/12 = \text{Actual}

\Delta T = \text{Average temperature difference between circulated heated water and unconditioned space air temperature (°F)}^{191}

\begin{center}
\text{Pipes in unconditioned basement:}
\end{center}

\begin{center}
\begin{tabular}{|c|c|}
\hline
Outdoor reset controls & ΔT (°F) \\
\hline
Boiler without reset control & 110 \\
Boiler with reset control & 70 \\
\hline
\end{tabular}
\end{center}

\begin{center}
\text{Pipes in crawl space:}
\end{center}

\textsuperscript{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.

\textsuperscript{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.

\textsuperscript{190} Weighted based on number of occupied residential housing units in each zone.

\textsuperscript{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)](https://example.com/)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>ΔT (°F)</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>
<td></td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>126</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>122</td>
<td>82</td>
<td></td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>120</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>120</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Weighted Average¹⁹²</td>
<td>125</td>
<td>85</td>
<td></td>
</tr>
</tbody>
</table>

\[ \eta_{\text{Boiler}} = \text{Efficiency of boiler} \]
\[ = 0.819 \] 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:

\[ \Delta \text{Therm} = \left( \frac{((1/0.5 \times 0.196) - (1/3.5 \times 0.589)) \times 10 \times 120 \times 1288}{0.819 \times 100,000} \right) = 4.2 \text{ therms} \]

**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 defined above for the remainder of the measure life.

**DEEMED LIFETIME OF EFFICIENT EQUIPMENT**

The expected measure life is assumed to be 18 years. Remaining life of existing equipment is assumed to be 6 years.

**DEEMED MEASURE COST**

Time of sale: The incremental capital cost for this measure is dependent on efficiency. Assumed incremental costs are provided below:

<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:

<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>

---

196 Baseline SEER and EER should be updated when new minimum federal standards become effective.
198 The "lifespan" of a central air conditioner is about 15 to 20 years (US DOE: [http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12440](http://www.energysavers.gov/your_home/space_heating_cooling/index.cfm/mytopic=12440)).
199 Assumed to be one third of effective useful life
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:

\[
\Delta k\text{WH} = \frac{(FLH_{cool} \times \text{Btu/hr} \times (1/\text{SEER}_{base} - 1/\text{SEER}_{ee}))}{1000}
\]

Early replacement\textsuperscript{204}:

\[
\begin{align*}
\Delta k\text{WH} \text{ for remaining life of existing unit (1st 6 years):} \\
& = \frac{(FLH_{cool} \times \text{Capacity} \times (1/\text{SEER}_{exist} - 1/\text{SEER}_{ee}))}{1000}; \\
\Delta k\text{WH} \text{ for remaining measure life (next 12 years):} \\
& = \frac{(FLH_{cool} \times \text{Capacity} \times (1/\text{SEER}_{base} - 1/\text{SEER}_{ee}))}{1000}
\end{align*}
\]

Where:

\[
\begin{align*}
FLH_{cool} & = \text{Full load cooling hours} \\
& = \text{dependent on location and building type}\textsuperscript{205}.
\end{align*}
\]

\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/Calc_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.
<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLHcool (single family)</th>
<th>FLHcool (multi family)</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>1035</td>
<td>940</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
<td>820</td>
</tr>
<tr>
<td>Weighted Average(\text{206})</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

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\(\text{207}\)

SEERbase = Seasonal Energy Efficiency Ratio of baseline unit (kBtu/kWh)

= 13\(\text{208}\)

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\(\text{209}\).

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:

\[\Delta k\text{WH} = \frac{(629 \times 36,000 \times (1/13 - 1/14.5))}{1000} = 180 \text{kWh}\]

Early replacement example: a 3 ton unit, with SEER rating of 14.5 replaces an existing unit in unknown location:

\[\Delta k\text{WH(for first 6 years)} = \frac{(629 \times 36,000 \times (1/10 - 1/14.5))}{1000} = 702 \text{kWh}\]

\[\Delta k\text{WH(for next 12 years)} = \frac{(629 \times 36,000 \times (1/13 - 1/14.5))}{1000} = 180 \text{kWh}\]

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.

\(\text{206}\) Weighted based on number of residential occupied housing units in each zone.

\(\text{207}\) 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.

\(\text{208}\) Based on Minimum Federal Standard;


\(\text{209}\) 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:
\[ \Delta kW = (\text{Capacity} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}}))/1000 \times CF \]

Early replacement\(^{210}\):
\[ \Delta kW \text{ for remaining life of existing unit (1st 6 years):} \]
\[ = ((\text{Capacity} \times (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{ee}}))/1000 \times CF); \]
\[ \Delta kW \text{ for remaining measure life (next 12 years):} \]
\[ = ((\text{Capacity} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}}))/1000 \times CF) \]

Where:
- \( \text{EER}_{\text{base}} \) = EER Efficiency of baseline unit
  - \( = 11.2^{211} \)
- \( \text{EER}_{\text{exist}} \) = EER Efficiency of existing unit
  - \( = \) Actual EER of unit should be used, if EER is unknown, use 9.2\(^{212}\)
- \( \text{EER}_{\text{ee}} \) = EER Efficiency of ENERGY STAR unit
  - \( = \) Actual installed or 12 if unknown
- \( \text{CF}_{\text{SSP}} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
  - \( = 68%^{213} \)
- \( \text{CF}_{\text{PJM}} \) = 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.
Time of sale example: a 3 ton unit with EER rating of 12:
\[ \Delta k_{\text{SSP}} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.68} \]
\[ = 0.146 \text{ kW} \]
\[ \Delta k_{\text{PJM}} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.466} \]
\[ = 0.100 \text{ kW} \]

Early replacement example: a 3 ton unit with EER rating of 12 replaces an existing unit:
\[ \Delta k_{\text{SSP (for first 6 years)}} = \frac{(36,000 \times (1/9.2 - 1/12))}{1000 \times 0.68} \]
\[ = 0.621 \text{ kW} \]
\[ \Delta k_{\text{SSP (for next 12 years)}} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.68} \]
\[ = 0.146 \text{ kW} \]
\[ \Delta k_{\text{PJM (for first 6 years)}} = \frac{(36,000 \times (1/9.2 - 1/12))}{1000 \times 0.466} \]
\[ = 0.425 \text{ kW} \]
\[ \Delta k_{\text{PJM (for next 12 years)}} = \frac{(36,000 \times (1/11.2 - 1/12))}{1000 \times 0.466} \]
\[ = 0.100 \text{ kW} \]

**Natural Gas Savings**

N/A

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

N/A

**Measure Code:** RS-HVC-CAC1-V07-180101

**Review Deadline:** 1/1/2021
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.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual; which can be found on the Energy Conservatory website (As of Oct 2014: http://www.energyconservatory.com/sites/default/files/documents/mod_3-4_dg700_-_new_flow_rings_-_cr_-_tpt_-_no_fr_switch_manual_ce_0.pdf)

2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table';

   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).215

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 years216.

DEEMED MEASURE COST

The actual duct sealing measure cost should be used.

LOADSHAPE

Loadshape R08 - Residential Cooling
Loadshape R09 - Residential Electric Space Heat

Loadshape R10 - Residential Electric Heating and Cooling (Shell Measures)

**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.

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \]
\[ CF_{SSP} = 68\%^{217} \]

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[ CF_{PJM} = 46.6\%^{218} \]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

*Methodology 1: Modified Blower Door Subtraction*

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

\[ \text{Duct Leakage (CFM}_{50DL} = (\text{CFM}_{50\text{Whole House}} - \text{CFM}_{50\text{Envelope Only}}) \times SCF} \]

Where:

- \( \text{CFM}_{50\text{Whole House}} \) = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential
- \( \text{CFM}_{50\text{Envelope Only}} \) = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.
- \( SCF \) = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed and using look up table provided by Energy Conservatory.

b) Calculate duct leakage reduction, convert to CFM_{25DL} and factor in Supply and Return Loss Factors

\[ \Delta \text{Duct Leakage Reduction (CFM}_{25DL} = (\text{Pre CFM}_{50DL} - \text{Post CFM}_{50DL}) \times 0.64 \times (SLF + RLF)} \]

Where:

- 0.64 = Converts CFM50 to CFM25^{219}
- SLF = Supply Loss Factor

---

^{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).
\[ \Delta k\text{Wh} = \Delta k\text{Wh}_{\text{cooling}} + \Delta k\text{Wh}_{\text{fan}} \]

\[ \Delta k\text{Wh}_{\text{cooling}} = \left( \frac{\Delta \text{CFM}_{25,DL}}{((\text{Capacity}_{\text{Cool}}/12,000) \times 400)} \times \text{FLH}_{\text{cool}} \times \text{Capacity}_{\text{Cool}} \times \text{TRF}_{\text{cool}} \right) / 1000 / \eta_{\text{Cool}} \]

\[ \Delta k\text{Wh}_{\text{fan}} = (\Delta \text{Therm}_{\text{s}} \times F_{e} \times 29.3) \]

Where:

\(\Delta \text{CFM}_{25,DL}\) = Duct leakage reduction in CFM25

= calculated above

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)\(^{224}\)

FLHcool = Full load cooling hours

Dependent on location as below\(^{225}\):

<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>
</tbody>
</table>

\(^{220}\) 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

\(^{221}\) Assumes 50% of leaks are in supply ducts.

\(^{222}\) 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

\(^{223}\) Assumes 50% of leaks are in return ducts.

\(^{224}\) 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

\(^{225}\) 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 Spaces

1000 = Converts Btu to kBtu

ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)
= Actual. If unknown assume the following:

<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

Fe = 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 Fe 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% Fe. 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:**
- CFM50\_Whole\_House = 4800 CFM50
- CFM50\_Envelope\_Only = 4500 CFM50
- House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

**After:**
- CFM50\_Whole\_House = 4600 CFM50
- CFM50\_Envelope\_Only = 4500 CFM50
- House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

**Duct Leakage:**
- CFM50\_DL\_before = (4800 – 4500) * 1.29
  = 387 CFM
- CFM50\_DL\_after = (4600 – 4500) * 1.39
  = 139 CFM

**Duct Leakage reduction at CFM25:**
- \( \Delta CFM25\_DL = (387 – 139) * 0.64 \times (0.5 + 0.25) \)
  = 119 CFM25

**Energy Savings:**
- \( \Delta kWh\_cooling = \left[ \left( \frac{119}{(36000/12000) \times 400} \right) \times 730 \times 36000 \times 1 \right] / 1000 / 11 + (212 \times 0.0314 \times 29.3) \)
  = 237 + 195
  = 432 kWh

**Heating savings for homes with electric heat:**

\[ \Delta kWh\_heating = \left( \frac{\Delta CFM25\_DL}{(Output\_Capacity\_Heat/12000) \times 400} \right) \times FLH\_heat \times Output\_Capacity\_Heat \times TRF\_heat / \eta\_heat / 3412 \]

Where:
- Output\_Capacity\_Heat = Heating output capacity (Btu/hr) of electric heat
- FLH\_heat = Full load heating hours
- \( \eta\_heat \) = 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.
Climate Zone (City based upon) | FLH_heat
--- | ---
4 (Belleville) | 1,266
5 (Marion) | 1,288
Weighted Average<sup>231</sup> | 1,821

TRF<sub>Heat</sub> = Thermal Regain Factor for heating by space type
= 0.40 for Semi-Conditioned Spaces
= 1.0 for Unconditioned Spaces<sup>232</sup>

η<sub>Heat</sub> = Efficiency in COP of Heating equipment
= Actual. If not available use<sup>233</sup>:

<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:

\[ \Delta \text{kWh}_{\text{heating}} = \frac{(119 / ((36,000/12,000) * 400)) * 1,754 * 36,000 * 1)}{2.5 / 3412} = 734 \text{kWh} \]

**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”

\[ \Delta \text{kWh} = \left( \frac{((\text{DE}_{\text{after}} - \text{DE}_{\text{before}}) / \text{DE}_{\text{after}}) * \text{FLH}_{\text{cool}} * \text{Capacity}_{\text{cool}} * \text{TRF}_{\text{cool}}) / 1000 / \eta_{\text{cool}}}{\text{ΔTherms} * F_e * 29.3} \right) + \Delta \text{Therms} \]

Where:

- \( \text{DE}_{\text{after}} \) = Distribution Efficiency after duct sealing
- \( \text{DE}_{\text{before}} \) = Distribution Efficiency before duct sealing

---

<sup>231</sup> Weighted based on number of occupied residential housing units in each zone.
<sup>232</sup> 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.
<sup>233</sup> 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\(^{234}\):

<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(^{235})</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\(^{236}\)

1000 = Converts Btu to kBtu

\(\eta_{\text{Cool}}\) = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)
= Actual. If unknown assume\(^{237}\):

<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:

\[
\begin{align*}
\text{DE}_{\text{before}} &= 0.85 \\
\text{DE}_{\text{after}} &= 0.92
\end{align*}
\]

Energy Savings:

\[
\Delta \text{kWh}_{\text{cooling}} = (((0.92 - 0.85)/0.92) \times 730 \times 36,000 \times 1) / 1000 / 11 + (212 \times 0.0314 \times 29.3)
\]

\[
= 182 + 195
\]

\[
= 377 \text{ kWh}
\]

Heating savings for homes with electric heat:

\[
\Delta \text{kWh}_{\text{heating}} = ((\text{DE}_{\text{after}} - \text{DE}_{\text{before}})/ \text{DE}_{\text{after}}) \times \text{FLH}_{\text{heat}} \times \text{OutputCapacityHeat} \times \text{TRF}_{\text{heat}} / \eta_{\text{heat}} / 3412
\]

Where:

\[
\text{OutputCapacityHeat} = \text{Heating output capacity (Btu/hr) of the electric heat = Actual}
\]

\[
\text{FLH}_{\text{heat}} = \text{Full load heating hours = Dependent on location as below}\text{238:}
\]

<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\text{239}</td>
<td>1,821</td>
</tr>
</tbody>
</table>

\[
\text{TRF}_{\text{heat}} = \text{Thermal Regain Factor for heating by space type = 0.40 for Semi-Conditioned Spaces = 1.0 for Unconditioned Spaces}\text{240}
\]

\[
\text{COP} = \text{Coefficient of Performance of electric heating system}\text{241 = Actual. If not available use}\text{242:}
\]

---

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>
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<th>COP Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Pump</td>
<td>Before 2006</td>
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<tr>
<td></td>
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<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>

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:

- $D_E_{after} = 0.92$
- $D_E_{before} = 0.85$

**Energy Savings:**

\[
\Delta k\text{Wh}_{\text{heating}} = \frac{(0.92 - 0.85)/0.92 \times 1,754 \times 36,000 \times 1}{2.5} / 3412
\]

\[
= 563 \text{ kWh}
\]

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[
\Delta k\text{W} = \Delta k\text{Wh}_{\text{cooling}} / \text{FLH}_{\text{cool}} \times \text{CF}
\]

Where:

- $\text{FLH}_{\text{cool}} = \text{Full load cooling hours}$
- 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>
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<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$^{244}$</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

- $\text{CF}_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)}$
- $= 68\%^{245}$

- $\text{CF}_{PJM} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)}$
- $= 46.6\%^{246}$

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.

$^{243}$ 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.

$^{244}$ Weighted based on number of occupied residential housing units in each zone.

$^{245}$ Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

$^{246}$ 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**

\[ \Delta \text{Therm} = \left( \frac{((\Delta \text{CFM}_{25DL}) \cdot (\text{InputCapacityHeat} \cdot 0.0123)) \cdot \text{FLH}_{\text{heat}} \cdot \text{InputCapacityHeat} \cdot \text{TRF}_{\text{heat}} \cdot (\eta_{\text{Equipment}} / \eta_{\text{System}})}{100,000} \right) \]

Where:

- \( \Delta \text{CFM}_{25DL} \) = Duct leakage reduction in CFM25
- \( \text{InputCapacityHeat} \) = Heating input capacity (Btu/hr) = Actual
- 0.0123 = Conversion of Capacity to CFM (0.0123CFM / Btu/hr)
- \( \text{FLH}_{\text{heat}} \) = 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>
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<td>2 (Chicago)</td>
<td>1,840</td>
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<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>

- \( \text{TRF}_{\text{heat}} \) = Thermal Regain Factor for heating by space type
  - 0.40 for Semi-Conditioned Spaces
  - 1.0 for Unconditioned Spaces \(^{250}\)
- 100,000 = Converts Btu to therms
- \( \eta_{\text{Equipment}} \) = Heating Equipment Efficiency

---

\(^{247}\) 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: \[0.829 \times (1 - 0.15) = 0.70\]
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:  
\[ \text{CFM50}_{\text{Whole House}} = 4800 \text{ CFM50} \]
\[ \text{CFM50}_{\text{Envelope Only}} = 4500 \text{CFM50} \]
House to duct pressure of 45 Pascals = 1.29 SCF (Energy Conservatory look up table)

After:  
\[ \text{CFM50}_{\text{Whole House}} = 4600 \text{ CFM50} \]
\[ \text{CFM50}_{\text{Envelope Only}} = 4500 \text{CFM50} \]
House to duct pressure of 43 Pascals = 1.39 SCF (Energy Conservatory look up table)

Duct Leakage:
\[ \text{CFM50}_{\text{DL before}} = (4800 - 4500) \times 1.29 = 387 \text{ CFM} \]
\[ \text{CFM50}_{\text{DL after}} = (4600 - 4500) \times 1.39 = 119 \text{ CFM} \]

Duct Leakage reduction at CFM25:
\[ \Delta\text{CFM25}_{\text{DL}} = (387 - 139) \times 0.64 \times (0.5 + 0.25) = 119 \text{ CFM25} \]

Energy Savings:
\[ \eta_{\text{System}} = 80\% \times 92\% = 74\% \]
\[ \Delta\text{Therm} = \frac{(119/ (105,000 \times 0.0123)) \times 1,754 \times 105,000 \times 1 \times (0.8/0.74)) / 100,000}{100,000} \]
\[ = 183 \text{ therms} \]

**Methodology 2: Evaluation of Distribution Efficiency**

\[ \Delta\text{Therm} = \frac{((\text{DE}_{\text{after}} - \text{DE}_{\text{before}})/ \text{DE}_{\text{after}}) \times \text{FLHheat} \times \text{InputCapacityHeat} \times \text{TRFheat} \times \left(\frac{\eta_{\text{Equipment}}}{\eta_{\text{System}}}\right)}{100,000} \]

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:

\[
\begin{align*}
\text{DE}_{\text{after}} &= 0.92 \\
\text{DE}_{\text{before}} &= 0.85
\end{align*}
\]

Energy Savings:

\[
\begin{align*}
\eta_{\text{System}} &= 80\% \times 85\% = 68\% \\
\Delta \text{Therm} &= \frac{(0.92 - 0.85)/(0.92) \times 1,754 \times 105,000 \times 1 \times (0.8/0.68)}{100,000} \\
&= 164 \text{ therm}
\end{align*}
\]

**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 years255.

DEEMED MEASURE COST
The capital cost for this measure is assumed to be $97256.

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.

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \]
\[ = 68\%^{257} \]

---


257 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
\[ CF_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[ = 46.6\%^{258} \]

\section*{Algorithm}

\section*{Calculation of Savings}

\section*{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 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:

\[ \Delta \text{kWh} = \text{Heating Savings} + \text{Cooling Savings} + \text{Shoulder Season Savings} \]
\[ = 418 + 263 + 51 \]
\[ = 732 \text{kWh} \]

\section*{Summer Coincident Peak Demand Savings}

\[ \Delta \text{kW} = \text{Cooling Savings} / \text{FLH\textunderscore cooling} \times \text{CF} \]

Where:

- **FLH\textunderscore 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.
<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>512</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>570</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>730</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,035</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>903</td>
</tr>
<tr>
<td>Weighted Average(^{262})</td>
<td>629</td>
</tr>
</tbody>
</table>

\(\text{CF}_{\text{SSP}}\) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour)  
\(\text{CF}_{\text{PJM}}\) = 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:

\[
\Delta kW_{\text{SSP}} = \frac{251}{629} \times 0.68 = 0.271 \text{ kW}
\]

\[
\Delta kW_{\text{SSP}} = \frac{251}{629} \times 0.466 = 0.186 \text{ kW}
\]

**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\(^{\text{266}}\) if in new furnace or 64.4 AFUE\(^{\text{267}}\) if in existing furnace

Using defaults:

For new Furnace = \(- (418 \times 0.03412)/0.95\)

= \(- 15.0 \text{ therms}\)

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.

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% (Energy Star Minimum)</td>
<td>$4268</td>
<td>$725</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:

$$\Delta \text{Therms} = \text{Gas}_\text{Boiler}_\text{Load} \times HF \times (1/\text{AFUE}(\text{base}) - 1/\text{AFUE}(\text{eff}))$$

Early replacement\(^{274}\):

$$\Delta \text{Therms} \text{ for remaining life of existing unit (1st 8 years):}$$

$$= \text{Gas}_\text{Boiler}_\text{Load} \times HF \times (1/\text{AFUE}(\text{exist}) - 1/\text{AFUE}(\text{eff}))$$

$$\Delta \text{Therms} \text{ for remaining measure life (next 17 years):}$$

$$= \text{Gas}_\text{Boiler}_\text{Load} \times HF \times (1/\text{AFUE}(\text{base}) - 1/\text{AFUE}(\text{eff}))$$

Where:

\begin{align*}
\text{Gas}_\text{Boiler}_\text{Load} & = \text{Estimate of annual household Load for gas boiler heated single-family homes.} \\
& = \text{or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent}^{277}.
\end{align*}

<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>

$$HF = \text{Household factor, to adjust heating consumption for non-single-family households.}$$

<table>
<thead>
<tr>
<th>Household Type</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family</td>
<td>100%</td>
</tr>
</tbody>
</table>

\(^{274}\) 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.
<table>
<thead>
<tr>
<th>Household Type</th>
<th>HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-Family</td>
<td>65%</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom</td>
</tr>
</tbody>
</table>

AFUE(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% 280.

AFUE(base) = Baseline Boiler Annual Fuel Utilization Efficiency Rating

= 82%

AFUE(eff) = Efficient Boiler Annual Fuel Utilization Efficiency Rating

= Actual. If unknown, use defaults dependent 281 on tier as listed below:

<table>
<thead>
<tr>
<th>Measure Type</th>
<th>AFUE(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><strong>Replacement Scenario for the Furnace</strong></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)

284 Table 8.3.3 The Technical support documents for federal residential appliance standards:

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). 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:

\[
\Delta \text{Therms} = \text{Gas\_Furnace\_Heating\_Load} \times HF \times \left( \frac{1}{\text{AFUE}(\text{base}) \times (1-\text{Derating}(\text{base}))} - \frac{1}{\text{AFUE}(\text{eff}) \times (1-\text{Derating}(\text{eff}))} \right)
\]

Early replacement\textsuperscript{288}:

\[
\Delta \text{Therms for remaining life of existing unit (1st 6 years)}:

= \text{Gas\_Furnace\_Heating\_Load} \times HF \times \left( \frac{1}{\text{AFUE}(\text{exist}) \times (1-\text{Derating}(\text{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\_Furnace\_Heating\_Load} \times 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:

\[
\text{Gas\_Furnace\_Heating\_Load}
\]

\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\textsuperscript{289} for gas furnace heated single-family homes. If location is unknown, assume the average below\textsuperscript{290}.

= Actual if informed by site-specific load calculations, ACCA Manual J or equivalent\textsuperscript{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%</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom\textsuperscript{293}</td>
</tr>
</tbody>
</table>

AFUE\textsuperscript{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\%\textsuperscript{294}.

AFUE\textsuperscript{base} = Baseline Furnace Annual Fuel Utilization Efficiency Rating

= Dependent on program type as listed below\textsuperscript{295}:

<table>
<thead>
<tr>
<th>Program Year</th>
<th>AFUE\textsuperscript{base}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time of Sale</td>
<td>80%</td>
</tr>
<tr>
<td>Early Replacement\textsuperscript{296}</td>
<td>90%</td>
</tr>
</tbody>
</table>

\textsuperscript{289} Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE).

\textsuperscript{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.

\textsuperscript{291} The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8\textsuperscript{th} 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.

\textsuperscript{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.

\textsuperscript{293} Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.

\textsuperscript{294} Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

\textsuperscript{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.

\textsuperscript{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\text{eff} = \text{Efficient Furnace Annual Fuel Utilization Efficiency Rating} \\
= \text{Actual. If unknown, assume 95\%}^{297}

\text{Derating(base)} = \text{Baseline furnace AFUE derating} \\
= 6.4\%^{298}

\text{Derating(eff)} = \text{Efficient furnace AFUE derating} \\
= 0\% \text{ if verified quality installation is performed} \\
= 6.4\% \text{ if verified quality installation is not performed}^{299}

### Time of Sale:

For example, a 95\% AFUE furnace purchased and installed with verified quality installation for an existing home near Rockford:

\[ \Delta \text{Therms} = 873 \cdot \left( \frac{1}{(0.8 \cdot (1 - 6.4\%))} - \frac{1}{(0.95 \cdot (1 - 0\%))} \right) = 247 \text{ therms} \]

For example, a 95\% AFUE furnace purchased and installed without verified quality installation for an existing home near Rockford:

\[ \Delta \text{Therms} = 873 \cdot \left( \frac{1}{(0.8 \cdot (1 - 6.4\%))} - \frac{1}{(0.95 \cdot (1 - 6.4\%))} \right) = 184 \text{ therms} \]

### Early Replacement:

For example, an existing functioning furnace with unknown efficiency is replaced with a 95\% furnace using quality installation in Rockford:

\[ \Delta \text{Therms for remaining life of existing unit (1st 6 years)}: \]

\[ = 873 \cdot \left( \frac{1}{(0.644 \cdot (1 - 6.4\%))} - \frac{1}{(0.95 \cdot (1 - 0\%))} \right) = 529 \text{ therms} \]

\[ \Delta \text{Therms for remaining measure life (next 14 years)}: \]

\[ = 873 \cdot \left( \frac{1}{(0.9 \cdot (1 - 6.4\%))} - \frac{1}{(0.95 \cdot (1 - 0\%))} \right) = 117 \text{ therms} \]

---

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

N/A

---

297 Minimum ENERGY STAR efficiency after 2.1.2012.
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.

c) **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 300:

<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.
### Existing System

<table>
<thead>
<tr>
<th>Existing System</th>
<th>Maximum efficiency for Actual</th>
<th>New Baseline</th>
</tr>
</thead>
<tbody>
<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: 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>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\(^{301}\) 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\(^{302}\); for <=55 gallon tanks = 0.675 – (0.0015 * storage size in gallons) and for tanks >55 gallon = 0.8012 – (0.00078 * 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\(^3\)\(^0\)\(^3\)\(^3\).

For early replacement, the remaining life of existing equipment is assumed to be 8 years\(^3\)\(^0\)\(^4\).

**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\(^3\)\(^0\)\(^5\)), minus the assumed installation cost of the baseline equipment ($1381 per ton for ASHP\(^3\)\(^0\)\(^6\) or $2011 for a new baseline 80% AFUE furnace or $3543 for a new 82% AFUE boiler\(^3\)\(^0\)\(^7\) and $952 per ton\(^3\)\(^0\)\(^8\) 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\(^3\)\(^0\)\(^9\). 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)\(^3\)\(^1\)\(^0\)

Loadshape R09 - Residential Electric Space Heat  (if replacing electric heat with no cooling)

Loadshape R10 - Residential Electric Heating and Cooling  (if replacing ASHP)

---

\(^3\)\(^0\)\(^3\) 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.

\(^3\)\(^0\)\(^4\) Assumed to be one third of effective useful life

\(^3\)\(^0\)\(^5\) Based on data provided in ‘Results of HomE geothermal and air source heat pump rebate incentives documented by IL electric cooperatives’. 

\(^3\)\(^0\)\(^6\) Based on data provided on Home Advisor website, providing national average ASHP cost based on 2465 cost submittals. http://www.homeadvisor.com/cost/heating-and-cooling/install-a-heat-pump/

\(^3\)\(^0\)\(^7\) 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.

\(^3\)\(^0\)\(^8\) 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).

\(^3\)\(^0\)\(^9\) All baseline replacement costs are consistent with their respective measures and include inflation rate of 1.91%.

\(^3\)\(^1\)\(^0\) 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.

\[
\begin{align*}
CF_{SSP} &= \text{Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)} \\
&= 72\%^{311} \\
CF_{PJM} &= \text{PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)} \\
&= 46.6\%^{312}
\end{align*}
\]

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

New Construction and Time of Sale (non-fuel switch only):

\[
\Delta kWh = \text{[Cooling savings]} + \text{[Heating savings]} + \text{[DHW savings]}
\]

\[
= [\text{FLHcool} \times \text{Capacity}_{cooling} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{Elecheat} \times \text{FLHheat} \times \text{Capacity}_{heating} \times (1/\text{HSPF}_{\text{ASHP}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412]
\]

New Construction and Time of Sale (fuel switch only): 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:

\[
\Delta kWh = \text{[Cooling savings]} + \text{[Heating savings from base ASHP to GSHP]} + \text{[DHW savings]}
\]

\[
= [\text{FLHcool} \times \text{Capacity}_{cooling} \times (1/\text{SEER}_{\text{base}} - 1/\text{EER}_{\text{PL}})/1000] + [\text{FLHheat} \times \text{Capacity}_{heating} \times (1/\text{HSPF}_{\text{ASHP}} - 1/(\text{COP}_{\text{PL}} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{ELEC}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412]
\]

Early replacement (non-fuel switch only):\(^{313}\)

\[
\Delta kWH \text{ for remaining life of existing unit (1st 8 years)}:
\]

\[\text{Based on analysis of metering results from 24 heat pumps in Ameren Illinois service territory in PYS coincident with AIC's 2010 system peak; 'Impact and Process Evaluation of Ameren Illinois Company’s Residential HVAC Program (PYS)'. }\]


\[\text{Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The average AC load over the PJM peak period (1-5pm, M-F, June through August) is divided by the maximum AC load during the year.}\]

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

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/EERPL)/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFexist – 1/(COPPL * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EFelec * GPD * Household * 365.25 * γWater * (TOUT – TIN) * 1.0) / 3412)]

ΔkWH for remaining life (next 17 years):

= [FLHcool * Capacity_cooling * (1/SEERbase – 1/EERPL)/1000] + [ElecHeat * FLHheat * Capacity_heating * (1/HSPFbase – 1/(COPPL * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EFelec * GPD * Household * 365.25 * γWater * (TOUT – TIN) * 1.0) / 3412)]

Early replacement - fuel switch only (see illustrative examples after Natural Gas section):

If measure is supported by gas utility only, ΔkWH = 0

If measure is supported by gas and electric utility or electric utility only, electric utility claim savings calculated below:

ΔkWh for remaining life of existing unit (1st 8 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/SEERexist – 1/EERPL)/1000] + [FLHheat * Capacity_heating * (1/HSPFASHP – 1/(COPPL * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EFelec * GPD * Household * 365.25 * γWater * (TOUT – TIN) * 1.0) / 3412)]

ΔkWh for remaining measure life (next 17 years):

= [Cooling savings] + [Heating savings from base ASHP to GSHP] + [DHW savings]

= [FLHcool * Capacity_cooling * (1/SEERbase – 1/EERPL)/1000] + [FLHheat * Capacity_heating * (1/HSPFASHP – 1/(COPPL * 3.412))/1000] + [ElecDHW * %DHWDisplaced * ((1/EFelec * GPD * Household * 365.25 * γWater * (TOUT – TIN) * 1.0) / 3412)]

Where:

FLHcool = Full load cooling hours

Dependent on location as below:\(^{314}\):

<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>Weighted Average(^{315})</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

Capacity_cooling = Cooling Capacity of Ground Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

SEERbase = SEER Efficiency of new replacement baseline unit

\(^{314}\) 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.

\(^{315}\) Weighted based on number of occupied residential housing units in each zone.
Existing Cooling System | SEERbase
---|---
Air Source Heat Pump | 14\(^{316}\)
Central AC | 13\(^{317}\)
No central cooling | 13\(^{318}\)

SEERexist = 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:

| Existing Cooling System | SEER_exist |
---|---
Air Source Heat Pump | 9.12\(^{319}\)
Central AC | 8.60\(^{320}\)
No central cooling | 13\(^{321}\)

SEER\(\text{ASHP}\) = SEER Efficiency of new baseline Air Source Heat Pump unit (for fuel switch)
= 14\(^{322}\)

EER\(\text{PL}\) = Part Load EER Efficiency of efficient GSHP unit\(^{323}\)
= 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\(^{324}\):

| Climate Zone (City based upon) | FLH_heat |
---|---
1 (Rockford) | 1,969
2 (Chicago) | 1,840
3 (Springfield) | 1,754
4 (Belleville) | 1,266
5 (Marion) | 1,288
Weighted Average\(^{325}\) | 1,821

\(^{318}\) Assumes that the decision to replace existing systems includes desire to add cooling.
\(^{319}\) Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
\(^{320}\) Ibid.
\(^{321}\) Assumes that the decision to replace existing systems includes desire to add cooling.
\(^{323}\) 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.
\(^{324}\) 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.
\(^{325}\) Weighted based on number of occupied residential housing units in each zone.
Capacity_heating = Heating Capacity of Ground Source Heat Pump (Btu/hr)

= Actual (1 ton = 12,000Btu/hr)

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\textsuperscript{326}</td>
</tr>
</tbody>
</table>

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 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>

HSPF_{ASHP} = Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)

= 8.2\textsuperscript{327}

COP_{PL} = Part Load Coefficient of Performance of efficient unit\textsuperscript{328}

= Actual Installed

3.412 = Constant to convert the COP of the unit to the Heating Season Performance Factor (HSPF).

ElecDHW = 1 if existing DHW is electrically heated

= 0 if existing DHW is not electrically heated

%DHWDisplaced = Percentage of total DHW load that the GSHP will provide

= Actual if known

= If unknown and if desuperheater installed assume 44%\textsuperscript{329}

= 0% if no desuperheater installed

EF_{ELEC} = Energy Factor (efficiency) of electric water heater

= Actual. If unknown or for new construction assume federal standard\textsuperscript{330}:

For \leq 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})

\textsuperscript{326} Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.


\textsuperscript{328} 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{329} Assumes that the desuperheater can provide two thirds of hot water needs for eight months of the year \(2/3 \times 2/3 = 44\%\).

\textsuperscript{330} 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 household$^{331}$
= 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>2.56$^{332}$</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms$^{333}$</td>
</tr>
</tbody>
</table>

365.25 = Days per year

γ\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
= 54°F$^{334}$

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.

### 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:

\[
\Delta kWh = [FLH_{cool} \times \text{Capacity}_{cooling} \times (1/\text{SEER}_{base} - 1/\text{EER}_{PL})/1000] + [FLH_{heat} \times \text{Capacity}_{heating} \times (1/HSPF_{base} - 1/((\text{COP}_{PL} \times 3.412))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times ((1/\text{EF}_{ELECEXIST} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{Water} \times (T_{OUT} - T_{IN}) \times 1.0) / 3412]]
\]

\[
\Delta kWh = [730 \times 36,000 \times (1/9.12 - 1/19) / 1000] + [1754 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412)) / 1000] + [1 \times 0.44 \times ((1/0.945 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412]]
\]

\[
= 494 + 3494 + 1328
\]

\[
= 5316 \text{ kWh}
\]

#### 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:

\[
\Delta kWh\text{ for remaining life of existing unit (1st 8 years):}
\]

\[
= [730 \times 36,000 \times (1/9.12 - 1/19) / 1000] + [1754 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412)) / 1000] + [0.44 \times 1 \times ((1/0.945 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412]]
\]

\[
= 1498 + 7401 + 1328
\]

\[
= 10,227 \text{ kWh}
\]

\[
\Delta kWh\text{ for remaining measure life (next 17 years):}
\]

\[
= (730 \times 36,000 \times (1/14 - 1/28) / 1000] + [1967 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412)) / 1000] + [0.44 \times 1 \times ((1/0.945 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412]]
\]

\[
= 494 + 3494 + 1328
\]

\[
= 5316 \text{ kWh}
\]

### SUMMER COINCIDENT PEAK DEMAND SAVINGS

#### New Construction and Time of Sale:

\[
\Delta kW = (\text{Capacity}_{cooling} \times (1/\text{EER}_{base} - 1/\text{EER}_{PL})/1000) \times \text{CF}
\]

#### Early replacement:

\[
\Delta kW\text{ for remaining life of existing unit (1st 8 years):}
\]

\[
= (\text{Capacity}_{cooling} \times (1/\text{EER}_{exist} - 1/\text{EER}_{PL})/1000) \times \text{CF}
\]

\[
\Delta kW\text{ for remaining measure life (next 17 years):}
\]

\[
= (\text{Capacity}_{cooling} \times (1/\text{EER}_{base} - 1/\text{EER}_{PL})/1000) \times \text{CF}
\]

Where:

\[
\text{EER}_{base} = \text{EER Efficiency of new replacement unit}
\]
### Existing Cooling System

<table>
<thead>
<tr>
<th></th>
<th>EER base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>11.8</td>
</tr>
<tr>
<td>Central AC</td>
<td>11</td>
</tr>
<tr>
<td>No central cooling</td>
<td>11</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</td>
</tr>
<tr>
<td>No central cooling</td>
<td>11</td>
</tr>
</tbody>
</table>

**EER\textunderscore FL**

= Full Load EER Efficiency of ENERGY STAR GSHP unit

**CF\textunderscore SSP**

= Summer System Peak Coincidence Factor for Central A/C (during system peak hour)

= 72%[sup]343\[/sup]

**CF\textunderscore PJM**

= PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

= 46.6%[sup]344\[/sup]

---

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


337 Assumes that the decision to replace existing systems includes desire to add cooling.


339 Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

340 Ibid.

341 Assumes that the decision to replace existing systems includes desire to add cooling.

342 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.


344 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:

\[
\Delta k_{W_{SSP}} = (36,000 \times (1/11.8 - 1/19))/1000 \times 0.72 = 0.83 \text{ kW}
\]

\[
\Delta k_{W_{PJM}} = (36,000 \times (1/11 - 1/19))/1000 \times 0.466 = 0.54 \text{ kW}
\]

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:

\[
\Delta k_{W_{SSP}} \text{ for remaining life of existing unit (1st 8 years)}:
= (36,000 \times (1/8.55 - 1/19))/1000 \times 0.72 = 1.67 \text{ kW}
\]

\[
\Delta k_{W_{SSP}} \text{ for remaining measure life (next 17 years)}:
= (36,000 \times (1/11.8 - 1/19))/1000 \times 0.72 = 0.83 \text{ kW}
\]

\[
\Delta k_{W_{PJM}} \text{ for remaining life of existing unit (1st 8 years)}:
= (36,000 \times (1/8.55 - 1/19))/1000 \times 0.466 = 1.08 \text{ kW}
\]

\[
\Delta k_{W_{PJM}} \text{ for remaining measure life (next 17 years)}:
= (36,000 \times (1/11.8 - 1/19))/1000 \times 0.466 = 0.54 \text{ kW}
\]

**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:

\[
\Delta \text{Therms} = [\text{Heating Savings}] + [\text{DHW Savings}]
\]

\[
= [\text{Replaced gas consumption} - \text{therm equivalent of GSHP source kWh}] + [\text{DHW Savings}]
\]

\[
= [(1 - \text{ElecHeat}) \times ([\text{Gas\_Heating\_Load}/\text{AFUEbase}] - (\text{kWhToTherm} \times \text{FLHeat} \times \text{Capacity\_heating} \times 1/(\text{COP}_{PL} \times 3.412))/1000]) + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS\_EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/100,000])
\]

If measure is supported by electric utility only, \(\Delta \text{Therms} = 0\)

If measure is supported by gas and electric utility, gas utility claim savings calculated below, (electric savings is provided in Electric Energy Savings section):

\[
\Delta \text{Therms} = [\text{Heating Savings}] + [\text{DHW Savings}]
\]

\[
= [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] + [\text{DHW Savings}]
\]

\[
= [(1 - \text{ElecHeat}) \times ([\text{Gas\_Heating\_Load}/\text{AFUEbase}] - (\text{kWhToTherm} \times \text{FLHeat} \times \text{Capacity\_heating} \times 1/(\text{COP}_{PL} \times 3.412))/1000]) + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times (1/\text{EF}_{\text{GAS\_EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/100,000])
\]
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:

\[
\Delta \text{Therms for remaining life of existing unit (1st 8 years)}: \\
= \text{[Heating Savings]} + \text{[DHW Savings]} \\
= \text{[Replaced gas consumption} - \text{therm equivalent of GSHP source kWh]} + \text{[DHW Savings]} \\
= \left[(1 - \text{ElecHeat}) \times \left\{ \left(\frac{\text{Gas\_Heating\_Load}}{\text{AFUExist}} \right) - \left(\frac{\text{kWhToTherm} \times \text{FLHeat} \times \text{Capacity\_heating} \times \left(1/(\text{COP}_{\text{PL}} \times 3.412)\right)/1000\right) \times \left(1 - \text{ElecDHW}\right) \times \%\text{DHWDisplaced} \times \left(1/ \text{EF}_{\text{GAS\_EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times \left(T_{\text{OUT}} - T_{\text{IN}}\right) \times 1.0 \right)/100,000 \right\} \right]
\]

\[
\Delta \text{Therms for remaining measure life (next 17 years)}: \\
= \left[(1 - \text{ElecHeat}) \times \left\{ \left(\frac{\text{Gas\_Heating\_Load}}{\text{AFUEbaseER}} \right) - \left(\frac{\text{kWhToTherm} \times \text{FLHeat} \times \text{Capacity\_heating} \times \left(1/\text{HSPF}_{\text{ASHP}}\right)/1000\right) \times \left(1 - \text{ElecDHW}\right) \times \%\text{DHWDisplaced} \times \left(1/ \text{EF}_{\text{GAS\_EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times \left(T_{\text{OUT}} - T_{\text{IN}}\right) \times 1.0 \right)/100,000 \right\} \right]
\]

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:

\[
\Delta \text{Therms for remaining life of existing unit (1st 8 years)}: \\
= \text{[Heating Savings]} + \text{[DHW Savings]} \\
= \text{[Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh]} + \text{[DHW Savings]} \\
= \left[(1 - \text{ElecHeat}) \times \left\{ \left(\frac{\text{Gas\_Heating\_Load}}{\text{AFUExist}} \right) - \left(\frac{\text{kWhToTherm} \times \text{FLHeat} \times \text{Capacity\_heating} \times \left(1/\text{HSPF}_{\text{ASHP}}\right)/1000\right) \times \left(1 - \text{ElecDHW}\right) \times \%\text{DHWDisplaced} \times \left(1/ \text{EF}_{\text{GAS\_EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times \left(T_{\text{OUT}} - T_{\text{IN}}\right) \times 1.0 \right)/100,000 \right\} \right]
\]

\[
\Delta \text{Therms for remaining measure life (next 17 years)}: \\
= \left[(1 - \text{ElecHeat}) \times \left\{ \left(\frac{\text{Gas\_Heating\_Load}}{\text{AFUEbaseER}} \right) - \left(\frac{\text{kWhToTherm} \times \text{FLHeat} \times \text{Capacity\_heating} \times \left(1/\text{HSPF}_{\text{ASHP}}\right)/1000\right) \times \left(1 - \text{ElecDHW}\right) \times \%\text{DHWDisplaced} \times \left(1/ \text{EF}_{\text{GAS\_EXIST}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times \left(T_{\text{OUT}} - T_{\text{IN}}\right) \times 1.0 \right)/100,000 \right\} \right]
\]

Where:

- \(\text{ElecHeat} = 1\) if existing building is electrically heated
- \(\text{ElecHeat} = 0\) if existing building is not electrically heated

- \(\text{Gas\_Heating\_Load}\) = Estimate of annual household heating load \(^{345}\) for gas furnace heated single-family homes. If location is unknown, assume the average below.
- \(\text{Gas\_Heating\_Load}\) = Actual if informed by site-specific load calculations, ACCA Manual J or equivalent\(^{346}\).

\(^{345}\) Heating load is used to describe the household heating need, which is equal to (gas consumption \(*\) AFUE).

\(^{346}\) The Air Conditioning Contractors of America Manual J, Residential Load Calculation 8\(^{th}\) 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.
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
= \( \frac{H_{\text{grid}}}{100000} \)

\( H_{\text{grid}} \) = 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:
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.

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.

Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.


Current values are:
- 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)
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\text{GAS EXIST} = \text{Energy Factor (efficiency) of existing gas water heater}

= Actual. If unknown assume federal standard\textsuperscript{352};

For \leq 55 \text{ gallons}: \quad 0.675 \, - \, (0.0015 \, \times \, \text{tank size})

For > 55 \text{ gallons} \quad 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:

\[
\Delta kWH = 0
\]

\[
\Delta \text{Therms} = \text{[Heating Savings]} + \text{[DHW Savings]}
\]

\[
= \text{[Replaced gas consumption – therm equivalent of GSHP source kWh]} + \text{[DHW Savings]}
\]

\[
= \left[ (1 - \text{ElecHeat}) \times ((\text{Gas_Heating_Load/AFUEbase}) - (\text{kWhtoTherm} \times \text{FLHheat} \times \text{Capacity_heating} \times 1/(\text{COP} \times 3.412)/(1000)) + [(1 - \text{ElecDHW}) \times \text{DHWDisplaced} \times (1/ \text{EF}_{\text{gas}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0] / 100,000) \right]
\]

\[
= [(1-0) \times ((714/0.80) - (10000/100000 \times 1754 \times 36000 \times 1/(4.4 \times 3.412))/(1000)) + [(1-0) \times (0.44 \times (1/0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1) / 100,000)]
\]

\[
= 472 + 70
\]

\[
= 542 \text{ therms}
\]

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:

\[
\Delta \text{kWh for remaining life of existing unit (1st 8 years):}
\]

\[
= \text{[Cooling savings]} + \text{[Heating savings from base ASHP to GSHP]} + \text{[DHW savings]}
\]

\[
= [(\text{FLHcool} \times \text{Capacity_cooling} \times (1/\text{SEER}_{\text{exist}} - (1/\text{EER}_{\text{PL}})/1000)) + [(\text{FLHheat} \times \text{Capacity_heating} \times (1/\text{HSPF}_{\text{ASHP}} - (1/\text{COP} \times 3.412))/1000) + [\text{ElecDHW} \times \text{DHWDisplaced} \times ((1/\text{EF}_{\text{elec}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 3412)]
\]

\[
= [(730\times 36000 \times (1/8.6 - 1/19)) / 1000] + [(1754 \times 36000 \times (1/8.2 - 1/(4.4 \times 3.412)))/1000]
\]

\[
+ [0 \times 0.44 \times ((1/0.904) \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412]
\]

\[
= 1673 + 3494 + 0
\]

\[
= 5167 \text{ kWh}
\]

Continued on next page.
Illustrative Example continued

$\Delta k\text{Wh for remaining measure life (next 17 years):}$

$$\Delta k\text{Wh} = [\text{Cooling savings}] + [\text{Heating savings}] + [\text{DHW savings}]$$

$$\Delta k\text{Wh} = [(\text{FLH}_{\text{cool}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{base}} - (1/\text{EER}_{\text{PL}}))/1000) + [(\text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{ASHP}} - (1/\text{COP}_{\text{PL}} \times 3.412)))/1000] + [\text{ElecDHW} \times \%\text{DHWDisplaced} \times (((1/\text{EF}_{\text{ELEC}}) \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0)/3412)]$$

$$\Delta k\text{Wh} = [(730 \times 36,000 \times (1/13 - 1/19))/1000] + [1754 \times 36,000 \times (1/8.2 - 1/(4.4 \times 3.412))/1000] + [0 \times 0.44 \times (((1/0.904) \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/3412)]$$

$$\Delta k\text{Wh} = 638 + 3494 + 0$$

$$\Delta k\text{Wh} = 4132 \text{ kWh}$$

$\Delta \text{Therms for remaining life of existing unit (1st 8 years):}$

$$\Delta \text{Therms} = [\text{Heating Savings}] + [\text{DHW Savings}]$$

$$\Delta \text{Therms} = [\text{Replaced gas consumption} - \text{therm equivalent of base ASHP source kWh}] + [\text{DHW Savings}]$$

$$\Delta \text{Therms} = [(1 - \text{ElecHeat}) \times ((\text{Gas}_{{\text{Heating}}}_{\text{Load}}/\text{AFUE}_{\text{exist}}) - (\text{kWh}_{\text{toTherm}} \times \text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times \text{ElecDHW}_{\text{toTherm}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0/100,000)]$$

$$\Delta \text{Therms} = [(1 - 0) \times (714/0.644) - (10000/100000 \times 1754 \times 36,000 \times 1/8.2)/1000)] + [(1 - 0) \times (0.44 \times (1/0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/100,000)]$$

$$\Delta \text{Therms} = 339 + 70$$

$$\Delta \text{Therms} = 408 \text{ therms}$$

$\Delta \text{Therms for remaining measure life (next 17 years):}$

$$\Delta \text{Therms} = [(1 - \text{ElecHeat}) \times ((\text{Gas}_{{\text{Heating}}}_{\text{Load}}/\text{AFUE}_{\text{baseER}}) - (\text{kWh}_{\text{toTherm}} \times \text{FLH}_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times 1/\text{HSPF}_{\text{ASHP}})/1000)] + [(1 - \text{ElecDHW}) \times \%\text{DHWDisplaced} \times \text{ElecDHW}_{\text{toTherm}} \times \text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0/100,000)]$$

$$\Delta \text{Therms} = [(1 - 0) \times (714/0.9) - (10000/100000 \times 1754 \times 36,000 \times 1/8.2)/1000)] + [(1 - 0) \times (0.44 \times (1/0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125-54) \times 1)/100,000)]$$

$$\Delta \text{Therms} = 23 + 70$$

$$\Delta \text{Therms} = 93 \text{ therms}$$

**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.

\[ Δ\text{Therms} = \left[ (1 - \text{ElecHeat}) \times \text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{base}} \right] + \left[ (1 - \text{ElecDHW}) \times \text{DHW}_\text{Displaced} \times \left( \frac{\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0}{100,000} \right) \right] / \text{AFUE}_{\text{exist}} \]

\[ Δ\text{kWh} = \left[ \text{GSHP}_\text{heating}_\text{consumption} \right] + \left[ \text{Cooling}_\text{savings} \right] + \left[ \text{DHW}_\text{savings}_\text{if_electric} \right] \]

### 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 calculate the annual savings for the remaining life (years 9-25):]

\[ Δ\text{Therms} = \left[ (1 - \text{ElecHeat}) \times \text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{exist}} \right] + \left[ (1 - \text{ElecDHW}) \times \text{DHW}_\text{Displaced} \times \left( \frac{\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0}{100,000} \right) \right] / \text{AFUE}_{\text{exist}} \]

\[ = \left[ (1 - 0) \times (714/0.644) \right] + \left[ (1 - 0) \times 0.44 \times (1 / 0.615 \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1) / 100,000 \right] \]

\[ = 1109 + 70 \]

\[ = 1179 \text{ therms} \]

\[ Δ\text{kWh} = - \left[ (\text{FLH}\text{heat} \times \text{Capacity}_\text{heating} \times (1/\text{COP}_{\text{PL}} \times 3.412))/1000 \right] + \left[ (\text{FLH}\text{cool} \times \text{Capacity}_\text{cooling} \times (1/\text{SEER}_{\text{exist1}} - 1/\text{EER}_{\text{PL}}))/1000 \right] + \left[ \text{ElecDHW} \times \text{DHW}_\text{Displaced} \times \left( \frac{\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0}{3412} \right) \right] / \text{SEER}_{\text{exist2}} \]

\[ = - \left[ (1754 \times 36,000 \times (1/(4.4 \times 3.412)))/1000 \right] + \left[ (730 \times 36,000 \times (1/8.6 - 1/19))/1000 \right] + \left[ 0 \times 0.44 \times ((1/0.904) \times 17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54) \times 1)/3412 \right] \]

\[ = -4206 + 1673 + 0 \]

\[ = -2533 \text{ kWh} \]

---

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\textsuperscript{355}) exhaust-only ventilation fan, quiet (< 2.0 sones) Continuous operation in accordance with recommended ventilation rate indicated by ASHRAE 62.2\textsuperscript{356}

DEFINITION OF BASELINE EQUIPMENT

New standard efficiency (average CFM/Watt of 3.1\textsuperscript{357}) exhaust-only ventilation fan, quiet (< 2.0 sones) operating in accordance with recommended ventilation rate indicated by ASHRAE 62.2 \textsuperscript{358}

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 19 years\textsuperscript{359}.

DEEMED MEASURE COST

Incremental cost per installed fan is $43.50 for quiet, efficient fans\textsuperscript{360}.

LOADSHAPE

Loadshape R11 - Residential Ventilation

COINCIDENCE FACTOR

The summer Peak Coincidence Factor is assumed to be 100% because the fan runs continuously.

\textsuperscript{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.

\textsuperscript{356} Bi-level controls may be used by efficient fans larger than 50 CFM

\textsuperscript{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.

\textsuperscript{358} On/off cycling controls may be required of baseline fans larger than 50CFM.

\textsuperscript{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.

\textsuperscript{360} VEIC analysis using cost data collected from wholesale vendor; http://www.westsidewholesale.com/.
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = (\text{CFM} \times (1/\eta_{\text{BASELINE}} - 1/\eta_{\text{EFFICIENT}})/1000) \times \text{Hours} \]

Where:
- CFM = Nominal Capacity of the exhaust fan
  = 50 CFM\(^{361}\)
- \(\eta_{\text{BASELINE}}\) = Average efficacy for baseline fan
  = 3.1 CFM/Watt\(^{362}\)
- \(\eta_{\text{EFFICIENT}}\) = Average efficacy for efficient fan
  = 8.3 CFM/Watt\(^{363}\)
- Hours = assumed annual run hours,
  = 8766 for continuous ventilation.

\[ \Delta \text{kWh} = \left(50 \times (1/3.1 - 1/8.3)/1000\right) \times 8766 \]
\[ \Delta \text{kWh} = 88.6 \text{kWh} \]

SUMMER COINCIDENT PEAK DEMAND SAVINGS

\[ \Delta \text{kW} = (\text{CFM} \times (1/\eta_{\text{BASELINE}} - 1/\eta_{\text{EFFICIENT}})/1000) \times \text{CF} \]

Where:
- CF = Summer Peak Coincidence Factor
  = 1.0 (continuous operation)
  Other variables as defined above

\[ \Delta \text{kW} = \left(50 \times (1/3.1 - 1/8.3)/1000\right) \times 1.0 \]
\[ \Delta \text{kW} = 0.0101 \text{kW} \]

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\(^{364}\).

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\(^{365}\).

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.

\[ CF_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \]
\[ = 68\%^{366} \]

\[ CF_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \]
\[ = 72\%^{367} \]

\(^{364}\) 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 (PY5)’.
Illinois Statewide Technical Reference Manual – 5.3.10 HVAC Tune Up (Central Air Conditioning or Air Source Heat Pump)

\[ CF_{PJM} = PJM \text{ Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[ = 46.6\% \] \(^{368}\)

### Algorithm

#### Calculation of Savings

**Electric Energy Savings**

\[ \Delta kWh_{\text{Central AC}} = (FLH_{\text{cool}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{CAC}}))/1000 \times MFe \]
\[ \Delta kWh_{\text{Air Source Heat Pump}} = ((FLH_{\text{cool}} \times \text{Capacity}_{\text{cooling}} \times (1/\text{SEER}_{\text{ASHP}}))/1000 \times MFe) + (FLH_{\text{heat}} \times \text{Capacity}_{\text{heating}} \times (1/\text{HSPF}_{\text{ASHP}}))/1000 \times MFe) \]

Where:

- \( FLH_{\text{cool}} \) = Full load cooling hours
- \( \text{Dependent on location as below:}^{369} \)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>FLH_{\text{cool}} Single Family</th>
<th>FLH_{\text{cool}} 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></td>
<td><strong>629</strong></td>
<td><strong>564</strong></td>
</tr>
</tbody>
</table>

- \( \text{Capacity}_{\text{cooling}} \) = Cooling capacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)
  - = Actual
- \( \text{SEER}_{\text{CAC}} \) = SEER Efficiency of existing central air conditioning unit receiving maintenance
  - = Actual. If unknown assume 10 SEER \(^{371}\)
- \( MFe \) = Maintenance energy savings factor
  - = 0.05\(^{372}\)
- \( \text{SEER}_{\text{ASHP}} \) = 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.
FLHheat = Full load heating hours

Dependent on location:

<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</td>
<td>1821</td>
</tr>
</tbody>
</table>

Capacity_heating = Heating capacity of equipment in Btu/hr (note 1 ton = 12,000 Btu/hr)

= Actual

HSPF<sub>ASHP</sub> = Heating Season Performance Factor of existing air source heat pump unit receiving maintenance

= Actual. If unknown assume 6.8 HSPF

For example, maintenance of a 3-ton, SEER 10 air conditioning unit in a single family house in Springfield:

\[
\Delta kWh_{CAC} = \frac{(730 \times 36,000 \times (1/10))}{1000 \times 0.05}
\]

= 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:

\[
\Delta kWh_{ASHP} = \left(\frac{(730 \times 36,000 \times (1/10))}{1000 \times 0.05}\right) + \left(\frac{1967 \times 36,000 \times (1/6.8))}{1000 \times 0.05}\right)
\]

= 652 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \text{Capacity}_\text{cooling} \times \frac{1}{\text{EER}} \times \text{Mfd} \times \text{CF}
\]

Where:

EER = EER Efficiency of existing unit receiving maintenance in Btu/H/Watts

= Calculate using Actual SEER

= -0.02*SEER<sup>2</sup> + 1.12*SEER

---

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.illinois.gov/ags) 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.

375 Weighted based on number of occupied residential housing units in each zone.

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

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:

\[ \Delta kW_{SSP} = \frac{36,000 \times 1}{9.2}/1000 \times 0.02 \times 0.68 \]
\[ \Delta kW_{SSP} = 0.0532 kW \]

\[ \Delta kW_{PJM} = \frac{36,000 \times 1}{9.2}/1000 \times 0.02 \times 0.466 \]
\[ \Delta kW_{PJM} = 0.0365 kW \]

**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**

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Calculations. Masters Thesis, University of Colorado at Boulder. Note this is appropriate for single speed units only.

\textsuperscript{378} Based on June 2010 personal conversation with Scott Pigg, author of Energy Center of Wisconsin, May 2008; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research” suggesting the average WI unit system draw of 2.8kW under peak conditions, and average peak savings of 50W.

\textsuperscript{379} Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\textsuperscript{380} 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)’.

\textsuperscript{381} 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.
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.
retail program) 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.

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**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta \text{kWh} = \% \text{ElectricHeat} \times \text{Elec\_Heating\_Consumption} \times \text{Heating\_Reduction} \times \text{HF} \times \text{Eff\_ISR} + (\Delta \text{Therms} \times F_e \times 29.3)
\]

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%</td>
</tr>
</tbody>
</table>

\[
\text{Elec\_Heating\_Consumption} = \text{Estimate of annual household heating consumption for electrically heated single-family homes}. If location and heating type is unknown, assume 15,678 kWh.
\]

---

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.
<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 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>

\(\Delta\text{Therms}\) = 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
29.3 \text{ kWh per therm}

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**

\[
\Delta \text{Therms} = \% \text{FossilHeat} \times \text{Gas\_Heating\_Consumption} \times \text{Heating\_Reduction} \times HF \times \text{Eff\_ISR}
\]

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%\textsuperscript{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\textsuperscript{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>

\textsuperscript{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.

\textsuperscript{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: \((0.24 \times 0.92) + (0.76 \times 0.8) = 0.83\) 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.
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.

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:

    | Existing System         | Maximum repair cost |
    |-------------------------|---------------------|
    | Air Source Heat Pump    | $276 per ton        |
    | Central Air Conditioner | $190 per ton        |

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.
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.

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.
### Ductless Heat Pumps

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>Efficiency Standard</th>
</tr>
</thead>
<tbody>
<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 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\(^401\).

For early replacement, the remaining life of existing equipment is assumed to be 6 years\(^402\).

**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\(^403\) or $2,011 for a new baseline 80% AFUE furnace or $3,543 for a new 82% AFUE boiler\(^404\) and $952 per ton\(^405\) for new baseline Central AC replacement).

<table>
<thead>
<tr>
<th>Unit Size</th>
<th>Full Install Cost(^406)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Ton</td>
<td>$3,000</td>
</tr>
<tr>
<td>1.5-Ton</td>
<td>$3750</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\(^407\). 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/Calc_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/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) 408
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 409.

For supplemental or limited zonal cooling:

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)} \]
\[ = 43.1\% \] 410

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)} \]
\[ = 28.0\% \] 411

For whole house cooling:

\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)} \]
\[ = 72\% \] 412

\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)} \]
\[ = 46.6\% \] 413

---

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:

$$\Delta \text{kWh} = [\text{Heating Savings from base ASHP to DMSHP}] + [\text{Cooling Savings}]$$

$$= [(\text{Capacity}_{\text{heat}} \times \text{EFLH}_{\text{heat}} \times (1/\text{HSPF}_{\text{Base}} - 1/\text{HSPF}_{\text{ee}})) / 1000] + [(\text{Capacity}_{\text{cool}} \times \text{EFLH}_{\text{cool}} \times (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{ee}})) / 1000]$$

Early replacement (non-fuel switch only)\(^{414}\):

**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).
$$= \left( \frac{\text{Capacity}_{\text{heat}} \cdot \text{EFLH}_{\text{heat}} \cdot (1/\text{HSPF}_{\text{base}} - 1/\text{HSPF}_{\text{exist}})}{1000} \right) + \left( \frac{\text{Capacity}_{\text{cool}} \cdot \text{EFLH}_{\text{cool}} \cdot (1/\text{SEER}_{\text{base}} - 1/\text{SEER}_{\text{exist}})}{1000} \right)$$

Where:

- **ElecHeat** = 1 if existing building is electrically heated
  = 0 if existing building is not electrically heated
- **Capacity**<sub>heat</sub> = Heating capacity of the ductless heat pump unit in Btu/hr
  = Actual
- **EFLH**<sub>heat</sub> = Equivalent Full Load Hours for heating. Depends on location. See table below

### Climate Zone (City based upon) | EFLH<sub>heat</sub><sup>415</sup>
---|---
1 (Rockford) | 1,520
2 (Chicago) | 1,421
3 (Springfield) | 1,347
4 (Belleville) | 977
5 (Marion) | 994
Weighted Average | 1,406

- **HSPF**<sub>base</sub> = Heating System Performance Factor of new replacement baseline heating system (kBtu/kWh)

<table>
<thead>
<tr>
<th>Existing Heating System</th>
<th>HSPF&lt;sub&gt;base&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>8.2</td>
</tr>
<tr>
<td>Electric Resistance</td>
<td>3.41&lt;sup&gt;416&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- **HSPF**<sub>exist</sub> = 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&lt;sub&gt;exist&lt;/sub&gt;&lt;sup&gt;417&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric resistance heating</td>
<td>3.412</td>
</tr>
<tr>
<td>Air Source Heat Pump</td>
<td>5.44&lt;sup&gt;418&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- **HSPF**<sub>ASHP</sub> = Heating Season Performance Factor for new ASHP baseline unit (for fuel switch)
  = 8.2<sup>419</sup>

---

<sup>415</sup> 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.

<sup>416</sup> Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

<sup>417</sup> Electric resistance has a COP of 1.0 which equals 1/0.293 = 3.41 HSPF.

<sup>418</sup> 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_{ee} = HSPF rating of new equipment (kbtu/kwh)
= Actual installed

Capacity_{cool} = the cooling capacity of the ductless heat pump unit in Btu/hr\(^{420}\).
= Actual installed

SEER_{base} = SEER Efficiency of new replacement baseline unit

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>SEER_{base}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Source Heat Pump</td>
<td>14(^{421})</td>
</tr>
<tr>
<td>Central AC</td>
<td>13(^{422})</td>
</tr>
<tr>
<td>No central cooling</td>
<td>13(^{423})</td>
</tr>
</tbody>
</table>

SEER_{ee} = SEER rating of new equipment (kbtu/kwh)
= Actual installed\(^{424}\)

SEER_{exist} = 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_{exist}(^{425})</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(^{426})</td>
</tr>
<tr>
<td>No existing cooling(^{427})</td>
<td>Make '1/SEER_{exist}' = 0</td>
</tr>
</tbody>
</table>

EFLH_{cool} = Equivalent Full Load Hours for cooling. Depends on location. See table below\(^{428}\).

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>EFLH_{cool}</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>

\(^{420}\) 1 Ton = 12 kBTU/hr
\(^{421}\) Minimum Federal Standard as of 1/1/2015;
\(^{423}\) Assumes that the decision to replace existing systems includes desire to add cooling.
\(^{424}\) Note that if only an EER rating is available, use the following conversion equation; EER_{base} = (-0.02 \times SEER_{base}^2) + (1.12 \times 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.
\(^{425}\) Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.
\(^{426}\) Estimated by converting the EER assumption using the conversion equation; EER_{base} = (-0.02 \times SEER_{base}^2) + (1.12 \times 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.
\(^{427}\) 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.
\(^{428}\) 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.
Ductless Heat Pumps

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:

$$\Delta k\text{Wh}_{\text{heat}} = (18000 \times 1421 \times (1/3.412 - 1/8))/1000 = 4,299 \text{ kWh}$$

$$\Delta k\text{Wh}_{\text{cool}} = (18000 \times 308 \times (1/8.0 - 1/14))/1000 = 297 \text{ kWh}$$

$$\Delta k\text{Wh} = 4,299 + 297 = 4,596 \text{ kWh}$$

**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:

$$\Delta kW \text{ for remaining life of existing unit (1st 6 years)}:$$

$$\Delta kW = (\text{Capacity}_{\text{cool}} \times (1/\text{EER}_{\text{exist}} - 1/\text{EER}_{\text{ee}})) / 1000 \times \text{CF}$$

$$\Delta kW \text{ for remaining measure life (next 12 years)}:$$

$$\Delta kW = (\text{Capacity}_{\text{cool}} \times (1/\text{EER}_{\text{base}} - 1/\text{EER}_{\text{ee}})) / 1000 \times \text{CF}$$

Where:

- \(\text{EER}_{\text{base}}\) = EER Efficiency of new replacement unit
- \(\text{EER}_{\text{exist}}\) = Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)

<table>
<thead>
<tr>
<th>Existing Cooling System</th>
<th>(\text{EER}_{\text{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>

\(^{429}\) 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 | EER_exist**
--- | ---
Air Source Heat Pump | 8.55\(^{434}\)
Central AC | 8.15\(^{435}\)
Room AC | 7.7\(^{436}\)
No existing cooling\(^{437}\) | Make ‘1/EER_exist’ = 0

\[ EER_{ee} = \text{Energy Efficiency Ratio of new ductless Air Source Heat Pump (kBtu/hr / kW)} \]
\[ = \text{Actual, If not provided convert SEER to EER using this formula: } 438 \]
\[ = (-0.02 \times \text{SEER}^2) + (1.12 \times \text{SEER}) \]

For supplemental or limited zonal cooling:
\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for DMSHP (during utility peak hour)} \]
\[ = 43.1\%^{439} \]
\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for DMSHP (average during PJM peak period)} \]
\[ = 28.0\%^{440} \]

For whole house cooling:
\[ CF_{SSP} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during utility peak hour)} \]
\[ = 72\%^{441} \]
\[ CF_{PJM} = \text{PJM Summer Peak Coincidence Factor for Heat Pumps (average during PJM peak period)} \]
\[ = 46.6\%^{442} \]

**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:

\[ \Delta \text{Therms} = [\text{Heating Savings}] \]
\[ = [\text{Replaced gas consumption – therm equivalent of DMSHP source kWh}] \]
\[ = [(1 - \text{ElecHeat}) \times ((\text{Gas Heating Load} / \text{AFUEbase}) - (\text{kWhToTherm} \times \text{Capacity}_{\text{heat}})) \]

---

\(^{434}\) 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 (PYS)’.

\(^{440}\) 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 (PYS)’.


\(^{442}\) 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\text{heat} \times \left(\frac{1}{\text{HSPF}_{\text{ee}}} / 1000\right)

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):

$\Delta$Therms = [Heating Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh]

= \left\{\left((1 - \text{ElecHeat}) \times \left(\frac{\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{base}}}{k\text{WhtoTherm} \times \text{Capacity}_{\text{heat}} \times EFLH_{\text{heat}} \times \left(\frac{1}{\text{HSPF}_{\text{ASHP}}} / 1000\right)}\right) \right\}

Early replacement for homes with existing gas heat:

If measure is supported by gas utility only, gas utility claim savings calculated below:

$\Delta$Therms for remaining life of existing unit (1st 6 years):

= [Heating Savings]

= [Replaced gas consumption – therm equivalent of DMSHP source kWh]

= \left\{\left((1 - \text{ElecHeat}) \times \left(\frac{\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{exist}}}{k\text{WhtoTherm} \times \text{Capacity}_{\text{heat}} \times EFLH_{\text{heat}} \times \left(\frac{1}{\text{HSPF}_{\text{ee}}} / 1000\right)}\right) \right\}

$\Delta$Therms for remaining measure life (next 12 years):

= \left\{\left((1 - \text{ElecHeat}) \times \left(\frac{\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{exist}}}{k\text{WhtoTherm} \times \text{Capacity}_{\text{heat}} \times EFLH_{\text{heat}} \times \left(\frac{1}{\text{HSPF}_{\text{ee}}} / 1000\right)}\right) \right\}

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:

$\Delta$Therms for remaining life of existing unit (1st 6 years):

= [Heating Savings]

= [Replaced gas consumption – therm equivalent of base ASHP source kWh]

= \left\{\left((1 - \text{ElecHeat}) \times \left(\frac{\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{exist}}}{k\text{WhtoTherm} \times \text{Capacity}_{\text{heat}} \times EFLH_{\text{heat}} \times \left(\frac{1}{\text{HSPF}_{\text{ee}}} / 1000\right)}\right) \right\}

$\Delta$Therms for remaining measure life (next 12 years):

= \left\{\left((1 - \text{ElecHeat}) \times \left(\frac{\text{Gas}_\text{Heating}_\text{Load}/\text{AFUE}_{\text{baseER}}}{k\text{WhtoTherm} \times \text{Capacity}_{\text{heat}} \times EFLH_{\text{heat}} \times \left(\frac{1}{\text{HSPF}_{\text{ASHP}}} / 1000\right)}\right) \right\}

Where:

\text{ElecHeat} = 1 \text{ if existing building is electrically heated}

= 0 \text{ if existing building is not electrically heated}

\text{Gas}_\text{Heating}_\text{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{Actual if informed by site-specific load calculations, ACCA Manual J or equivalent}^{444}.

---

\textit{443} Heating load is used to describe the household heating need, which is equal to (gas consumption * AFUE)

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
= \( H_{grid} / 100000 \)

\( H_{grid} \) = 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). 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.

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.

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.

Average nameplate efficiencies of all Early Replacement qualifying equipment in Ameren PY3-PY4.

Assumes that Federal Standard will have been increased to 90% by the time the existing unit would have to have been replaced.

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.

\[
Δ\text{Therms} = [\text{Heating Consumption Replaced}]^{450} = [(1 – \text{ElecHeat}) \times ((\text{Gas}_\text{Heating}_\text{Load}/\text{AFUEbase})]
\]

\[
ΔkWh = - [\text{DMSHP heating consumption}] + \text{[Cooling savings]}^{451} = - [(\text{Capacity}_\text{heat} \times \text{EFLH}_{\text{heat}} \times 1/\text{HSPFee})/1000] + [(\text{Capacity}_\text{cool} \times \text{EFLH}_{\text{cool}} \times (1/\text{SEER}_{\text{Base}} - 1/\text{SEER}_{\text{exist}})) / 1000]
\]

**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 AFUEexist 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\(^ {452}\) 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 ‘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\(^ {453}\):

- 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

---

**CALCULATION OF ENERGY SAVINGS**

**Electric Energy Savings**

\[
\Delta \text{kWh} = \Delta \text{Therms} \times F_e \times 29.3
\]

Where:

\[
\Delta \text{Therms} = \text{as calculated below}
\]

\[
F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption}
\]

\[
= 3.14\%^{455}
\]

---


\(^{455}\) \(F_e\) is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a
29.3 \[ = \text{kWh per therm} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

N/A

**NATURAL GAS SAVINGS**

1. Verified Quality Maintenance:

\[
\Delta \text{Therms} = \left( \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \times HF \times \left( \frac{1}{(AFUE \times (1 - \text{Derating}_{\text{pre}}))} - \frac{1}{(AFUE \times (1 - \text{Derating}_{\text{post}}))} \right) \right)
\]

Where:

- \( \Delta \text{Therms} \): Estimate of annual household heating load for gas furnace heated single-family homes. If location is unknown, assume the average below.
- \( \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \): 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_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%</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom</td>
</tr>
</tbody>
</table>

- \( AFUE \): Furnace Annual Fuel Utilization Efficiency Rating
- \( = \) Actual

*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.*

*Heating load is used to describe the household heating need, which is equal to \( \text{gas consumption} \times \text{AFUE} \).*

*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.*


*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.*

*Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations.*
Derating$_{\text{pre}}$  = Furnace AFUE Derating before HVAC SAVE tune-up
= 6.4\% 461

Derating$_{\text{post}}$  = Furnace AFUE Derating after HVAC SAVE tune-up
= 0\%

2. Other Tune-Up Programs:

\[ \text{\Delta Therms} = (\text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \times \text{HF} \times (1/ \text{Eff}_{\text{before}} - 1/ (\text{Eff}_{\text{before}} + \text{Ei}))) \]

Where:

\( \text{Gas}_\text{Furnace}_\text{Heating}_\text{Load} \) = Estimate of annual household heating load\(^{462}\) for gas furnace heated single-family homes. If location is unknown, assume the average below\(^{463}\).

\( \text{Actual if informed by site-specific load calculations, ACCA Manual J or equivalent}^{464} \).

<table>
<thead>
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<tr>
<td>Average</td>
<td>793</td>
</tr>
</tbody>
</table>

\( \text{HF} \) = Household factor, to adjust heating consumption for non-single-family households.

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<th>Household Type</th>
<th>HF</th>
</tr>
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<tr>
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<td>100%</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>65% 465</td>
</tr>
<tr>
<td>Actual</td>
<td>Custom 466</td>
</tr>
</tbody>
</table>

\( \text{Eff}_{\text{before}} \) = Efficiency of the furnace before the tune-up
= Actual

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 years468

DEEMED MEASURE COST

The cost of this measure is $612469

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
Algorithm

Calculation of Energy Savings

Electric Energy Savings

N/A

Summer Coincident Peak Demand Savings

NA

Natural Gas Savings

\[ \Delta \text{Therms} = \text{Gas\_Boiler\_Load} \times (1/\text{AFUE}) \times \text{Savings Factor} \]

Where:

\text{Gas\_Boiler\_Load}^{470} = \text{Estimate of annual household Load for gas boiler heated single-family homes. If location is unknown, assume the average below}^{471}.

\text{= or Actual if informed by site-specific load calculations, ACCA Manual J or equivalent}^{472}.

<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>

\text{AFUE} = \text{Existing Condensing Boiler Annual Fuel Utilization Efficiency Rating}

\text{= Actual.}

\text{SF} = \text{Savings Factor, 5\%}^{473}

---

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.

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.

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 (see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure).

DEEMED MEASURE COST

Incremental cost of unit is $46.

LOADSHAPE

R06 - Residential Indoor Lighting
R11 - Residential Ventilation

---

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.
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**

\[
\Delta \text{kWh} = \Delta\text{kWh}_{\text{fan}} + \Delta\text{kWh}_{\text{light}}
\]

\[
\Delta\text{kWh}_{\text{fan}} = \left(\text{Days} \times \text{FanHours} \times \left(\%\text{Low}_{\text{base}} \times \text{WattsLow}_{\text{base}}\right) + \left(\%\text{Med}_{\text{base}} \times \text{WattsMed}_{\text{base}}\right) + \left(\%\text{High}_{\text{base}} \times \text{WattsHigh}_{\text{base}}\right)/1000\right) - \left(\text{Days} \times \text{FanHours} \times \left(\%\text{Low}_{\text{ES}} \times \text{WattsLow}_{\text{ES}}\right) + \left(\%\text{Med}_{\text{ES}} \times \text{WattsMed}_{\text{ES}}\right) + \left(\%\text{High}_{\text{ES}} \times \text{WattsHigh}_{\text{ES}}\right)/1000\right)
\]

\[
\Delta\text{kWh}_{\text{light}} = \text{see } 5.5.1 \text{ ENERGY STAR Compact Fluorescent Lamp measure.}
\]

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

\(^{478}\) All fan default assumptions are based upon assumptions provided in the ENERGY STAR Ceiling Fan Savings Calculator;
= 40%

\( \text{Watts}_{\text{LowES}} \) = Fan wattage at Low speed of ENERGY STAR

\( \text{Watts}_{\text{MedES}} \) = Fan wattage at Medium speed of ENERGY STAR

\( \text{Watts}_{\text{HighES}} \) = Fan wattage at High speed of ENERGY STAR

\( \%_{\text{MedES}} \) = Percent of time spent at Medium speed of ENERGY STAR

\( \%_{\text{HighES}} \) = Percent of time spent at High speed of ENERGY STAR

\( \%_{\text{LowES}} \) = Actual. If unknown use 6 watts

\( \%_{\text{MedES}} \) = 40%

\( \%_{\text{HighES}} \) = 20%

\( \%_{\text{LowES}} \) = Actual. If unknown use 23 watts

\( \%_{\text{MedES}} \) = Actual. If unknown use 56 watts

For ease of reference, the fan assumptions are provided below in table form:

<table>
<thead>
<tr>
<th></th>
<th>Low Speed</th>
<th>Medium Speed</th>
<th>High Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Time at Given Speed</td>
<td>40%</td>
<td>40%</td>
<td>20%</td>
</tr>
<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 \( \text{Watts}_{\text{Base}} \) and \( \text{Watts}_{\text{EE}} \) is unknown, assume the following:

\( \text{Watts}_{\text{Base}} \) = 3 x 43 = 129 W

\( \text{Watts}_{\text{EE}} \) = 1 x 42 = 42 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:

\[ \Delta \text{kWh}_{\text{fan}} = (365.25*3*[(0.4*15)+(0.4*34)+(0.2*67)]/1000) - (365.25*3*[(0.4*6)+(0.4*23)+(0.2*56)]/1000) \]

\[ = 36.2 - 25.0 = 11.2 \text{ kWh} \]

\[ \Delta \text{kWh}_{\text{light}} = ((129 - 42)/1000) * 759 * 1.06 \]

\[ = 70.0 \text{ kWh} \]

\[ \Delta \text{kWh} = 11.2 + 70 \]

\[ = 81.2 \text{ kWh} \]

Using the default assumptions provided above, the deemed savings is 81.2 kWh.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta kW = \Delta kW_{\text{fan}} + \Delta kW_{\text{light}} \]

\[ \Delta kW_{\text{fan}} = ((\text{Watts}_{\text{HighBase}} - \text{Watts}_{\text{HighES}})/1000) * C_{\text{fan}} \]
\[ \Delta k_{\text{light}} = \text{see 5.5.1 ENERGY STAR Compact Fluorescent Lamp measure.} \]

Where:

\[ CF_{\text{fan}} = \text{Summer Peak coincidence factor for ventilation savings} \]
\[ = 30\% \] \text{\cite{479}}

\[ CF_{\text{light}} = \text{Summer Peak coincidence factor for lighting savings} \]
\[ = 7.1\% \] \text{\cite{480}}

**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:

\[ \Delta k_{\text{fan}} = \frac{(67 - 56)}{1000} \times 0.3 \]
\[ = 0.0033 \text{ kW} \]

\[ \Delta k_{\text{light}} = \frac{(129 - 42)}{1000} \times 1.11 \times 0.071 \]
\[ = 0.0068 \text{ kW} \]

\[ \Delta k = 0.0033 + 0.0068 \]
\[ = 0.010 \text{ kW} \]

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**

\text{\cite{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 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117\_RLW\_CF%20Res%20RA\_C.pdf)}

\text{\cite{480} Based on lighting logger study conducted as part of the PYS/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.\textsuperscript{485}

**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\textsuperscript{486} based upon equipment life only.\textsuperscript{487}

**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\textsuperscript{488}, or other program types actual costs are still preferable\textsuperscript{489} but if unknown then the average incremental cost for the new installation measure is assumed to be $175\textsuperscript{490}.

**LOADSHAPE**

\[ \Delta k\text{W} \rightarrow \text{Loadshape R10 - Residential Electric Heating and Cooling} \]
\[ \Delta k\text{W}_{\text{heating}} \rightarrow \text{Loadshape R09 - Residential Electric Space Heat} \]
\[ \Delta k\text{W}_{\text{cooling}} \rightarrow \text{Loadshape R08 - Residential Cooling} \]

**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.

\[ CF_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)} \]
\[ CF_{\text{SSP}} = 34\% \textsuperscript{491} \]
\[ CF_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[ CF_{\text{PJM}} = 23.3\% \textsuperscript{492} \]

\textsuperscript{485} Based on Opinion Dynamics Corporation, “ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study”, Appendix 3: Detailed Mail Survey Results, p34, April 2013.
\textsuperscript{486} Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007
\textsuperscript{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.
\textsuperscript{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.
\textsuperscript{489} Including any one-time software integration or annual software maintenance, and or individual device energy feature fees.
\textsuperscript{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.
\textsuperscript{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).
\textsuperscript{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.)
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWh^{493} = \Delta kWh_{heating} + \Delta kWh_{cooling} \]

\[ \Delta kWh_{heating} = \frac{\%ElectricHeat \times Elec\_Heating\_Consumption \times Heating\_Reduction \times HF \times Eff\_ISR + (\Delta \text{Therms} \times F_e \times 29.3)}{100} \]

\[ \Delta kWh_{cool} = \frac{\%AC \times (FLH \times Btu/hr \times 1/\text{SEER})/1000 \times Cooling\_Reduction \times Eff\_ISR}{100} \]

Where:

\[ \%ElectricHeat = \frac{\%\text{Electric Heat}}{100} \]

<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

\[ = \text{Estimate of annual household heating consumption for electrically heated single-family homes}^{495} \]

If location and heating type is unknown, assume 15,678 kWh\(^{496}\)

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Electric Resistance</th>
<th>Electric Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elec_Heating_Consumption (kWh)</td>
<td>Elec_Heating_Consumption (kWh)</td>
</tr>
<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>

ΔTherms = Therm savings if Natural Gas heating system

= See calculation in Natural Gas section below

Fe = Furnace Fan energy consumption as a percentage of annual fuel consumption

= 3.14%

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 Fe 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% Fe. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference.
Thermostat control of air conditioning?

<table>
<thead>
<tr>
<th>Thermostat control of air conditioning?</th>
<th>%AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>100%</td>
</tr>
<tr>
<td>No</td>
<td>0%</td>
</tr>
<tr>
<td>Unknown</td>
<td>66%</td>
</tr>
<tr>
<td>Unknown Multi-Family</td>
<td>46%</td>
</tr>
<tr>
<td>Unknown Single Family</td>
<td>87%</td>
</tr>
</tbody>
</table>

**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 average</td>
<td>629</td>
<td>564</td>
<td>293</td>
</tr>
</tbody>
</table>

**Btu/hr** = Size of AC unit. (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>SEER</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

---


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\(^{511}\):

\[ = 8.0\%^{512} \]

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:

\[
\Delta kWH = \Delta kWH_{heating} + \Delta kWH_{cooling}
\]

\[
= 1 \times 10,464 \times 5.6\% \times 100\% \times 100\% + (0 \times 0.0314 \times 29.3) + 100\% \times ((730 \times 33,600 \times (1/9.12))/1000) \times 8\% \times 100\%
\]

\[
= 586\text{kWh} + 215\text{kWh}
\]

\[
= 801\text{kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = %AC \times (\text{Cooling}\_\text{Reduction} \times \text{Btu/hr} \times (1/\text{EER})) / 1000 \times \text{EFF}\_\text{ISR} \times \text{CF}
\]

Where:

\[ \text{EER} = \text{Energy Efficiency Ratio of existing cooling system (kBtu/hr / kW)} \]

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

\[ \text{EER} = (-0.02 \times \text{SEER}_\text{exist}^2) + (1.12 \times \text{SEER}_\text{exist})^{513} \]

If SEER or EER rating unavailable use:

<table>
<thead>
<tr>
<th>Cooling System</th>
<th>EER(^{514})</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>

\[ \text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Central A/C (during system peak hour)} \]

\[ = 34\%^{515} \]

\[ \text{CF}_{\text{PJM}} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]

---

\(^{511}\) 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.)
\[ \Delta \text{Therms} = \% \text{Fossil Heat} \times \text{Gas}_\text{Heating}_\text{Consumption} \times \text{Heating Reduction} \times \text{HF} \times \text{Eff_ISR} \]

Where:

\[ \% \text{Fossil Heat} = \text{Percentage of heating savings assumed to be Natural Gas} \]

<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%</td>
</tr>
</tbody>
</table>

\[ \Delta \text{W}_{\text{SSP}} = 100\% \times 8\% \times 33,600 \times (1/8.15)/1000 \times 100\% \times 34\% \]
\[ = 0.11 \text{ kW} \]

\[ \Delta \text{W}_{\text{PJM}} = 100\% \times 8\% \times 33,600 \times (1/8.15)/1000 \times 100\% \times 23.3\% \]
\[ = 0.077 \text{ kW} \]

**NATURAL GAS ENERGY SAVINGS**

\[ \Delta \text{Therms} = \% \text{Fossil Heat} \times \text{Gas}_\text{Heating}_\text{Consumption} \times \text{Heating Reduction} \times \text{HF} \times \text{Eff_ISR} \]

Where:

\[ \% \text{Fossil Heat} = \text{Percentage of heating savings assumed to be Natural Gas} \]

**Gas\_Heating\_Consumption**

\[ = \text{Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below} \]

<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: \((0.24 \times 0.92) + (0.76 \times 0.8) = 0.83\)). 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.
### Climate Zone (City based upon) | Gas_Heating_Consumption (therms)
---|---
5 (Marion) | 676
Average | 955

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:

\[
\Delta\text{Therms} = 1.0 * 1005 * 5.6\% * 100\% * 100\%
\]

\[
= 56.28 \text{ therms}
\]

**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:

\[
\Delta \text{kWh} = \frac{\left(\frac{1}{R_{\text{exist}}} - \frac{1}{R_{\text{new}}}\right) \times (L \times C) \times \Delta T \times 8,766}{\eta_{\text{DHW}} / 3413}
\]

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\textsuperscript{521}

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 \textsuperscript{522}

8,766 = Hours per year

ηDHW = Recovery efficiency of electric hot water heater

= 0.98 \textsuperscript{523}

3412 = Conversion from Btu to kWh

For example, insulating 5 feet of 0.75” pipe with R-5 wrap:

\[ ΔkWh = \frac{(1/Rexist – 1/Rnew) * (L * C) * ΔT * 8,766}{ηDHW / 3412} \]

\[ = \frac{(1/1 – 1/(1+5)) * (5 * 0.196) * 60 * 8766}{0.98 /3412} \]

\[ = 128 \text{ kWh} \]

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.

\[ ΔkWh = \frac{(1/Rexist – 1/Rnew) * (L * C) * ΔT * 8,766}{ηDHW / 3412} \]

\[ = \frac{(1/1 – 1/(1+5)) * (3 * 0.196) * 60 * 8766}{0.98 /3412} \]

\[ = 77.1 \text{ kWh per 3ft length} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ ΔkW = ΔkWh / 8766 \]

Where:

\[ ΔkWh = \text{kWh savings from pipe wrap installation} \]

\[ 8766 = \text{Number of hours in a year (since savings are assumed to be constant over year).} \]

\textsuperscript{521} Navigant Consulting Inc., April 2009; “Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets”, p77.

\textsuperscript{522} Assumes 125°F water leaving the hot water tank and average temperature of basement of 65°F.

\textsuperscript{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:

\[
\Delta \text{Therm} = \frac{\left(\frac{1}{R_{\text{exist}}} - \frac{1}{R_{\text{new}}}\right) \times (L \times C) \times \Delta T \times 8,766 \times (100,000)}{\eta_{\text{DHW}}}
\]

Where:

\[
\eta_{\text{DHW}} = \text{Recovery efficiency of gas hot water heater} = 0.78 \quad 524
\]

Other variables as defined above

For example, insulating 5 feet of 0.75” pipe with R-5 wrap:

\[
\Delta \text{Therm} = \frac{\left(\frac{1}{1} - \frac{1}{1+5}\right) \times (5 \times 0.196) \times 60 \times 8766}{0.78 / 100,000} = 5.51 \text{ therms}
\]

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.

\[
\Delta \text{Therm} = \frac{\left(\frac{1}{R_{\text{exist}}} - \frac{1}{R_{\text{new}}}\right) \times (L \times C) \times \Delta T \times 8,766 \times (100,000)}{\eta_{\text{DHW}}}
\]

\[
= \frac{\left(\frac{1}{1} - \frac{1}{1+5}\right) \times (3 \times 0.196) \times 60 \times 8766}{0.78 / 100,000} = 3.30 \text{ therms per 3ft length}
\]

**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 \( 0.675 - (0.0015 \times \text{storage size in gallons}) \) and for tanks 55 - 100 gallon \( 0.8012 - (0.00078 \times \text{storage size in gallons}) \)\(^{525}\). 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\(^{527}\).

---


\(^{526}\) 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](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.\(^{528}\)

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.\(^{529}\) 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:

\[
\Delta \text{Therms} = \left( \frac{1}{\text{EF}_{\text{BASE}}} - \frac{1}{\text{EF}_{\text{EFFICIENT}}} \right) \times (\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 100,000
\]

Early replacement\(^{530}\):

\[
\Delta \text{Therms for remaining life of existing unit (1st 4 years)}: \\
= \left( \frac{1}{\text{EF}_{\text{EXISTING}}} - \frac{1}{\text{EF}_{\text{EFFICIENT}}} \right) \times (\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0) / 100,000
\]

\[
\Delta \text{Therms for remaining measure life (next 9 years)}:
\]


\(^{529}\) 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%.

\(^{530}\) 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).
\[
= (1/ \text{EF}_{\text{BASE}} - 1/\text{EF}_{\text{EFFICIENT}}) \times (\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 )/100,000
\]

Where:

\begin{align*}
\text{EF}_{\text{Baseline}} &= \text{Energy Factor rating for baseline equipment} \\
\text{For} \leq 55 \text{ gallons:} &\quad 0.675 - (0.0015 \times \text{tank size}) \\
\text{For} > 55 \text{ gallons:} &\quad 0.8012 - (0.00078 \times \text{tank size}) \\
\text{EF}_{\text{Efficient}} &= \text{Energy Factor Rating for efficient equipment} \\
\text{EF}_{\text{Existing}} &= \text{Energy Factor rating for existing equipment} \\
\text{GPD} &= \text{Gallons Per Day of hot water use per person} \\
\text{Household} &= \text{Average number of people per household}
\end{align*}

\begin{array}{|c|c|}
\hline
\text{Water Heater Type} & \text{EF}_{\text{Efficient}} \\
\hline
\text{Condensing Gas Storage} & 0.80 \\
\text{Gas Storage} & 0.67 \\
\text{Tankless whole-house} & 0.82 \times 0.91 = 0.75 \\
\hline
\end{array}

\begin{array}{|c|c|}
\hline
\text{Household Unit Type} & \text{Household} \\
\hline
\text{Single-Family - Deemed} & 2.56^{534} \\
\text{Multi-Family - Deemed} & 2.1^{535} \\
\text{Custom} & \text{Actual Occupancy or Number of Bedrooms}^{536} \\
\hline
\end{array}

\begin{align*}
365.25 &= \text{Days per year, on average}
\end{align*}

\text{531} \text{ 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.}

\text{532} \text{ Based on DCEO Efficient Living Program Data for a sample size of 157 gas water heaters.}


\text{536} \text{ 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.}
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°F\(^{537}\)

1.0 = 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 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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\(^{537}\) US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL
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:

For <=55 gallons: \[0.96 - (0.0003 \times \text{rated volume in gallons})\]
For >55 gallons: \[2.057 - (0.00113 \times \text{rated volume in gallons})\]

DEEMED LIFETIME OF EFFICIENT EQUIPMENT

The expected measure life is assumed to be 13 years.

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.

LOADSHAPE

Loadshape R03 - Residential Electric DHW

COINCIDENCE FACTOR

The summer Peak Coincidence Factor is assumed to be 12%.

---

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 * hours in peak period) / ([annual kWh savings / FLH] * hours in peak period) = (0.1 kW * 5 hours) / [(2100 kWh (default assumptions) / 2533 hours) * 5 hours] = 0.12
CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \left( \frac{1}{\text{EF}_{\text{BASE}} - 1/\text{EF}_{\text{EFFICIENT}}} \right) \times \text{GPD} \times \text{Household} \times 365.25 \times y_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 \times \frac{\text{kWh}_{\text{cooling}} - \text{kWh}_{\text{heating}}}{3412} \]

Where:

- \( \text{EF}_{\text{BASE}} \) = Energy Factor (efficiency) of standard electric water heater according to federal standards\(^{542}\):
  - For \( \leq 55 \) 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
- \( y_{\text{Water}} \) = 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.
Heat Pump Water Heaters

\[ = 54^\circ F \]

\[ 1.0 \]

\[ 3412 \]

\[ = \text{Heat Capacity of water (1 Btu/lb}\cdot\circ F) \]

\[ = \text{Conversion from Btu to kWh} \]

\[ \text{kWh\_cooling} = \text{Cooling savings from conversion of heat in home to water heat} \]

\[ = \left( \left( \frac{(GPD \cdot \text{Household} \cdot 365.25 \cdot \gamma_{\text{Water}} \cdot (T_{\text{OUT}} - T_{\text{IN}}) \cdot 1.0}{3412} \right) - \left( \frac{(1/E_{\text{NEW}} \cdot GPD \cdot \text{Household} \cdot 365.25 \cdot \gamma_{\text{Water}} \cdot (T_{\text{OUT}} - T_{\text{IN}}) \cdot 1.0}{3412} \right) \right) \cdot \text{LF} \cdot 27\% / \text{COP}_{\text{COOL}} / \text{LM} \]

Where:

\[ \text{LF} = \text{Location Factor} \]

\[ = 1.0 \text{ for HPWH installation in a conditioned space} \]

\[ = 0.5 \text{ for HPWH installation in an unknown location} \]

\[ = 0.0 \text{ for installation in an unconditioned space} \]

\[ 27\% = \text{Portion of reduced waste heat that results in cooling savings} \]

\[ \text{COP}_{\text{COOL}} = \text{COP of central air conditioning} \]

\[ = \text{Actual, if unknown, assume 3.08 (10.5 SEER / 3.412)} \]

\[ \text{LM} = \text{Latent multiplier to account for latent cooling demand} \]

\[ = 1.33 \]

\[ \text{kWh\_heating} = \text{Heating cost from conversion of heat in home to water heat (dependent on heating fuel)} \]

\[ = \left( \left( \frac{(GPD \cdot \text{Household} \cdot 365.25 \cdot \gamma_{\text{Water}} \cdot (T_{\text{OUT}} - T_{\text{IN}}) \cdot 1.0}{3412} \right) - \left( \frac{(1/E_{\text{NEW}} \cdot GPD \cdot \text{Household} \cdot 365.25 \cdot \gamma_{\text{Water}} \cdot (T_{\text{OUT}} - T_{\text{IN}}) \cdot 1.0}{3412} \right) \right) \cdot \text{LF} \cdot 49\% / \text{COP}_{\text{HEAT}} \cdot (1 - \%\text{NaturalGas}) \]

Where:

\[ 49\% = \text{Portion of reduced waste heat that results in increased heating load} \]

\[ \text{COP}_{\text{HEAT}} = \text{COP of electric heating system} \]

\[ = \text{actual. If not available use} \]

---


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](http://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.
### System Type

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP&lt;sub&gt;Heat (COP Estimate) = (HSPF/3.413)*0.85&lt;/sub&gt;</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;553&lt;/sup&gt;</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

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:

\[
\Delta kWh = \left[\frac{1 / 0.945 - 1 / 2.0}{17.6 \times 2.56 \times 365.25 \times 8.33 \times (125 - 54)}\right] / 3412 + 166.3 - 0
\]

\[
= 1759 \ kWh
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

- **Hours** = Full load hours of water heater  
  = 2533<sup>554</sup>

- **CF** = Summer Peak Coincidence Factor for measure  
  = 0.12<sup>555</sup>

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:

\[
kW = \frac{1759}{2533} \times 0.12
\]

\[
= 0.083 \ kW
\]

**NATURAL GAS SAVINGS**

\[
\Delta\text{Therms} = -\left(\left(\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 \right) / 3412\right) - \left(\left(\text{GPD} \times \text{Household} \times 365.25 \times \gamma_{\text{Water}} \times (T_{\text{OUT}} - T_{\text{IN}}) \times 1.0 \right) / 3412\right) / \eta_{\text{Heat}} \times \text{EF} \times 0.49 \times 0.03412 / \eta_{\text{Heat}} \times \%\text{NaturalGas}
\]

Where:

- **\Delta\text{Therms}** = Heating cost from conversion of heat in home to water heat for homes with Natural Gas

---

<sup>553</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>554</sup> Full load hours assumption based on Efficiency Vermont analysis of Itron eShapes.

<sup>555</sup> 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
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. kWh\textsubscript{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.

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.

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:

\[(0.24 * 0.92) + (0.76 * 0.8) * (1 - 0.15) = 0.70\]

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):
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.$^{560}$

DEEMED MEASURE COST

For time of sale or new construction the incremental cost for this measure is $3$^{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 $8$^{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%.$^{563}$

---


$^{561}$ 2011, Market research average of $3.$

$^{562}$ Includes assess and install labor time of $5 (20min @ $15/hr)

$^{563}$ 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.

\[
\Delta kWh = \%\text{ElectricDHW} \times \left( (\text{GPM}_{\text{base}} \times \text{L}_{\text{base}} - \text{GPM}_{\text{low}} \times \text{L}_{\text{low}}) \times \text{Household} \times 365.25 \times \text{DF} / \text{FPH} \right) \times \text{EPG}_{\text{electric}} \times \text{ISR}
\]

Where:

- \%\text{ElectricDHW} = \text{proportion of water heating supplied by electric resistance heating}

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%\text{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%565</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.
  - = 1.39566 or custom based on metering studies567 or if measured during DI: = Measured full throttle flow \times 0.83 \text{ throttling factor}568

- \text{GPM}_{\text{low}} = \text{Average flow rate, in gallons per minute, of the low-flow faucet aerator “as-used”}
  - = 0.94569 or custom based on metering studies570 or if measured during DI: = Rated full throttle flow \times 0.95 \text{ throttling factor}571

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 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>4.5[^72]</td>
</tr>
<tr>
<td>Bathroom</td>
<td>1.6[^73]</td>
</tr>
<tr>
<td>If location unknown (total for household): Single-Family</td>
<td>9.0[^74]</td>
</tr>
<tr>
<td>If location unknown (total for household): Multi-Family</td>
<td>6.9[^75]</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>4.5[^76]</td>
</tr>
<tr>
<td>Bathroom</td>
<td>1.6[^77]</td>
</tr>
<tr>
<td>If location unknown (total for household): Single-Family</td>
<td>9.0[^78]</td>
</tr>
<tr>
<td>If location unknown (total for household): Multi-Family</td>
<td>6.9[^79]</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>2.5[^80]</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1[^81]</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms[^82]</td>
</tr>
</tbody>
</table>


[^73] Ibid.

[^74] One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[^75] One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.


[^77] Ibid.

[^78] One kitchen faucet plus 2.83 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.

[^79] One kitchen faucet plus 1.5 bathroom faucets. Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.


[^82] 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></th>
<th>FPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Kitchen Faucets Per Home (KFPH)</td>
<td></td>
</tr>
<tr>
<td>Bathroom Faucets Per Home (BFPH): Single-Family</td>
<td>2.83</td>
</tr>
<tr>
<td>Bathroom Faucets Per Home (BFPH): Multi-Family</td>
<td>1.5</td>
</tr>
<tr>
<td>If location unknown (total for household): Single-Family</td>
<td>3.83</td>
</tr>
<tr>
<td>If location unknown (total for household): Multi-Family</td>
<td>2.5</td>
</tr>
</tbody>
</table>

EPG_electric = Energy per gallon of water used by faucet supplied by electric water heater

\[
\text{EPG}_{\text{electric}} = \frac{(8.33 \times 1.0 \times (\text{WaterTemp} - \text{SupplyTemp}))}{(\text{RE}_{\text{electric}} \times 3412)}
\]

\[
= \frac{(8.33 \times 1.0 \times (86 - 54.1))}{(0.98 \times 3412)}
\]

= 0.0795 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 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*0.75)+(0.3*0.9)=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*93)+(0.3*86)=0.91.

= 98% \(^{588}\)

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>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Install - Single Family</td>
</tr>
<tr>
<td>Direct Install – Multi Family Kitchen</td>
</tr>
<tr>
<td>Direct Install – Multi Family Bathroom</td>
</tr>
<tr>
<td>Efficiency Kit Bathroom Aerator</td>
</tr>
<tr>
<td>Efficiency Kit Kitchen Aerator</td>
</tr>
<tr>
<td>Distributed School Efficiency Kit Aerator</td>
</tr>
</tbody>
</table>

For example, a direct installed kitchen low flow faucet aerator in a single-family electric DHW home:

\[
\Delta k\text{Wh} = 1.0 \times \left( \frac{(1.39 \times 4.5 - 0.94 \times 4.5) \times 2.56 \times 365.25 \times 0.75}{1} \right) \times 0.0969 \times 0.95
\]

= 131 kWh

For example, a direct installed bath low flow faucet aerator in a multi-family electric DHW home:

\[
\Delta k\text{Wh} = 1.0 \times \left( \frac{(1.39 \times 1.6 - 0.94 \times 1.6) \times 2.1 \times 365.25 \times 0.90}{1.5} \right) \times 0.0795 \times 0.95
\]

= 25.0 kWh

For example, a direct installed low flow faucet aerator in unknown faucet in a single-family electric DHW home:

\[
\Delta k\text{Wh} = 1.0 \times \left( \frac{(1.39 \times 9.0 - 0.94 \times 9.0) \times 2.56 \times 365.25 \times 0.795}{3.83} \right) \times 0.0919 \times 0.95
\]

= 68.6 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

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.

\(^{592}\) From Navigant memo, “Nicor Gas energySMART Energy Saving Kits Program In Service Rate and Process Analysis”, August 28, 2015.

\(^{593}\) Ibid.
\( \Delta k\text{Wh} \) = calculated value above

\( \text{Hours} \) = Annual electric DHW recovery hours for faucet use per faucet

\( \text{Hours per faucet} = \left( (\text{GPM}_{\text{base}} \times \text{L}_{\text{base}}) \times \text{Household} / \text{FPH} \times 365.25 \times \text{DF} \right) \times 0.545 / \text{GPH} \)

<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 \times 4.5) \times 2.56/1 \times 365.25 \times 0.75 \times 0.545 / 25.5)</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>Bathroom</td>
<td>((1.39 \times 1.6) \times 2.56/2.83 \times 365.25 \times 0.9 \times 0.545 / 25.5)</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>((1.39 \times 9.0) \times 2.56/3.83 \times 365.25 \times 0.795 \times 0.545 / 25.5)</td>
<td>52</td>
</tr>
<tr>
<td>Multi Family</td>
<td>Kitchen</td>
<td>((1.39 \times 4.5) \times 2.1/1 \times 365.25 \times 0.75 \times 0.545 / 25.5)</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Bathroom</td>
<td>((1.39 \times 1.6) \times 2.1/1.5 \times 365.25 \times 0.9 \times 0.545 / 25.5)</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Unknown</td>
<td>((1.39 \times 6.9) \times 2.1/2.5 \times 365.25 \times 0.795 \times 0.545 / 25.5)</td>
<td>50</td>
</tr>
</tbody>
</table>

\( \text{GPH} \) = Gallons per hour recovery of electric water heater calculated for 70.9F temp rise (125-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.

\( \text{CF} \) = Coincidence Factor for electric load reduction

\( \Delta k\text{Wh} = 131/94 \times 0.022 = 0.0306 \text{ kW} \)

**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:

\( \%\text{FossilDHW} = \) 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>

\( \text{EPG}_{\text{gas}} = \) Energy per gallon of Hot water supplied by gas

---

594 54.5% is the proportion of hot 120F water mixed with 54.1F supply water to give 90F mixed faucet water.

595 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

596 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
\[
= (8.33 \times 1.0 \times (\text{WaterTemp} - \text{SupplyTemp})) / (\text{RE}_\text{gas} \times 100,000)
\]

\[
= 0.00341 \text{ Therm/gal for SF homes (Bath)},
0.00415 \text{ Therm/gal for SF homes (Kitchen)},
0.00394 \text{ Therm/gal for SF homes (Unknown)}
\]

\[
= 0.00397 \text{ Therm/gal for MF homes (Bath)},
0.00484 \text{ Therm/gal for MF homes (Kitchen)},
0.00459 \text{ Therm/gal for MF homes (Unknown)}
\]

\[
\text{RE}_\text{gas} = \text{Recovery efficiency of gas water heater}
\]

\[
= 78\% \text{ For SF homes}^{597}
\]

\[
= 67\% \text{ For MF homes}^{598}
\]

\[
100,000 = \text{Converts Btus to Therms (btu/Therm)}
\]

Other variables as defined above.

For example, a direct-installed kitchen low flow faucet aerator in a fuel DHW single-family home:

\[
\Delta\text{Therms} = 1.0 \times (((1.39 \times 4.5 - 0.94 \times 4.5) \times 2.56 \times 365.25 \times 0.75) / 1) \times 0.00415 \times 0.95
\]

\[
= 5.60 \text{ Therms}
\]

For example, a direct installed bath low flow faucet aerator in a fuel DHW multi-family home:

\[
\Delta\text{Therms} = 1.0 \times (((1.39 \times 1.6 - 0.94 \times 1.6) \times 2.1 \times 365.25 \times 0.90) / 1.5) \times 0.003974 \times 0.95
\]

\[
= 1.25 \text{ Therms}
\]

For example, a direct installed low flow faucet aerator in unknown faucet in a fuel DHW single-family home:

\[
\Delta\text{Therms} = 1.0 \times (((1.39 \times 9.0 - 0.94 \times 9.0) \times 2.56 \times 365.25 \times 0.795) / 3.83) \times 0.00394 \times 0.95
\]

\[
= 2.94 \text{ Therms}
\]

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

\[
\Delta\text{gallons} = ((\text{GPM}_\text{base} \times \text{L}_\text{base} - \text{GPM}_\text{low} \times \text{L}_\text{low}) \times \text{Household} \times 365.25 \times \text{DF} / \text{FPH}) \times \text{ISR}
\]

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 $7 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 $12 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: Oreto 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

\[
\Delta \text{kWh} = \% \text{ElectricDHW} \times ((GPM_{base} \times L_{base} - GPM_{low} \times L_{low}) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH}) \\
\times \text{EPG_{electric}} \times \text{ISR}
\]

Where:

<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>

<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>

\(GPM_{low}\) = 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>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 GPM</td>
</tr>
<tr>
<td>1.75 GPM</td>
</tr>
<tr>
<td>1.5 GPM</td>
</tr>
<tr>
<td>Custom or Actual606</td>
</tr>
</tbody>
</table>

\(L_{base}\) = 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 flow rate.

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\textsuperscript{608}

Household = Average number of people per household

<table>
<thead>
<tr>
<th>Household Unit Type\textsuperscript{609}</th>
<th>Household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Family - Deemed</td>
<td>2.56\textsuperscript{610}</td>
</tr>
<tr>
<td>Multi-Family - Deemed</td>
<td>2.1\textsuperscript{611}</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual Occupancy or Number of Bedrooms\textsuperscript{612}</td>
</tr>
</tbody>
</table>

SPCD = Showers Per Capita Per Day
= 0.6\textsuperscript{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\textsuperscript{614}</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>1.3\textsuperscript{615}</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual</td>
</tr>
</tbody>
</table>

EPG\textsubscript{electric} = Energy per gallon of hot water supplied by electric
= (8.33 * 1.0 * (\text{ShowerTemp} - \text{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\textdegree)
ShowerTemp = Assumed temperature of water
= 101\textdegree \textsuperscript{616}

for efficient showerhead and faucet aerators.
\textsuperscript{608} Ibid.
\textsuperscript{609} If household type is unknown, as may be the case for time of sale measures, then single family deemed value shall be used.
\textsuperscript{611} ComEd PY3 Multi-Family Evaluation Report REVISED DRAFT v5 2011-12-08.docx
\textsuperscript{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.
\textsuperscript{613} Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
\textsuperscript{614} Based on findings from a 2009 ComEd residential survey of 140 sites, provided by Cadmus.
\textsuperscript{615} Ibid.
\textsuperscript{616} Cadmus and Opinion Dynamics Showerhead and Faucet Aerator Meter Study Memorandum dated June 2013, directed to Michigan Evaluation Working Group.
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</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:

\[
\Delta k\text{Wh} = 1.0 \times ((2.67 \times 7.8 - 1.5 \times 7.8) \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.117 \times 0.98
\]

= 328 kWh

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

\[
\Delta k\text{Wh} = \text{calculated value above}
\]

Hours = Annual electric DHW recovery hours for showerhead use

= \((\text{GPM} \text{base} \times \text{L} \text{base}) \times \text{Household} \times \text{SPCD} \times 365.25 \) \times 0.712623 / GPH

= 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.
\[ = 27.51 \]
\[ = \text{Coincidence Factor for electric load reduction} \]
\[ = 0.0278^{624} \]

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**

\[ \Delta \text{Therms} = \%\text{FossilDHW} \times \left( \left( \text{GPM}_{\text{base}} \times L_{\text{base}} \right) \times \left( \text{GPM}_{\text{low}} \times L_{\text{low}} \right) \right) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH} \times \text{EPG}_{\text{gas}} \times \text{ISR} \]

Where:

- \%\text{FossilDHW} = \text{proportion of water heating supplied by Natural Gas heating}

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%\text{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>

\[ \text{EPG}_{\text{gas}} = \text{Energy per gallon of Hot water supplied by gas} \]
\[ = \left( 8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp}) / (\text{RE}_{\text{gas}} \times 100,000) \right) \]
\[ = 0.00501 \text{ Therm/gal for SF homes} \]
\[ = 0.00583 \text{ Therm/gal for MF homes} \]

\[ \text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater} \]
\[ = 78\% \text{ For SF homes}^{626} \]
\[ = 67\% \text{ For MF homes}^{627} \]

\[^{624}\text{Calculated as follows: Assume 11\% showers take place during peak hours (based on: Oreo et al, “The end uses of hot water in single family homes from flow trace analysis”, 2001.). There are 65 days in the summer peak period, so the percentage of total annual aerator use in peak period is 0.11 \times 65/365 = 1.96\%. The number of hours of recovery during peak periods is therefore assumed to be 1.96\% \times 369 = 7.23 hours of recovery during peak period where 369 equals the average annual electric DHW recovery hours for showerhead use including SF and MF homes with Direct Install and Retrofit/TOS measures. There are 260 hours in the peak period so the probability you will see savings during the peak period is 7.23/260 = 0.0278}\]

\[^{625}\text{Default assumption for unknown fuel is based on EIA Residential Energy Consumption Survey (RECS) 2009 for Midwest Region, data for the state of IL. If utilities have specific evaluation results providing a more appropriate assumption for homes in a particular market or geographical area then that should be used}\]

\[^{626}\text{DOE Final Rule discusses Recovery Efficiency with an average around 0.76 for Gas Fired Storage Water heaters and 0.78 for standard efficiency gas fired tankless water heaters up to 0.95 for the highest efficiency gas fired condensing tankless water heaters. These numbers represent the range of new units however, not the range of existing units in stock. Review of AHRI Directory suggests range of recovery efficiency ratings for new Gas DHW units of 70-87\%. Average of existing units is estimated at 78\%}\]

\[^{627}\text{Water heating in multi-family buildings is often provided by a larger central boiler. This suggests that the average recovery efficiency is somewhere between a typical central boiler efficiency of 0.59 and the 0.75 for single family homes. An average efficiency of 0.67 is used for this analysis as a default for multi-family buildings}\]
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**

\[ \Delta \text{gallons} = ((\text{GPM}_\text{base} \times \text{L}_\text{base} - \text{GPM}_\text{low} \times \text{L}_\text{low}) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH}) \times \text{ISR} \]
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**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**
For homes with electric DHW tanks:

\[
\Delta kWh = \frac{(U \times A \times (T_{pre} - T_{post}) \times \text{Hours} \times \text{ISR})}{(3412 \times \text{RE}_{\text{electric}})}
\]

Where:

- \( U \) = Overall heat transfer coefficient of tank (Btu/Hr\(^*\)°F-ft\(^2\)).
- \( U \) = 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; $A = 24.99\text{ft}^2$

<table>
<thead>
<tr>
<th>Capacity (gal)</th>
<th>$A (\text{ft}^2)$</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>

$T_{pre}$ = Actual hot water setpoint prior to adjustment

$T_{post}$ = Actual new hot water setpoint, which may not be lower than 120 degrees

### Default Hot Water Temperature Inputs

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{pre}$</td>
<td>135</td>
</tr>
<tr>
<td>$T_{post}$</td>
<td>120</td>
</tr>
</tbody>
</table>

$\text{Hours}$ = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

$\text{ISR}$ = 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

$RE_{\text{electric}}$ = Recovery efficiency of electric hot water heater

= 0.98

A deemed savings assumption, where site specific assumptions are not available would be as follows:

$$\Delta kW = \frac{(U * A * (T_{pre} – T_{post}) * \text{Hours} * \text{ISR})}{(3412 * \text{RE}_{\text{electric}})}$$

$$\Delta kW = \frac{((0.083 * 24.99) * (135 – 120) * 8766 * 1.0)}{(3412 * 0.98)}$$

= 81.6 kWh

### Summer Coincident Peak Demand Savings

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

Where:

$\text{Hours}$ = 8766

$\text{CF}$ = 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](http://www.ahridirectory.org/ahridirectory/pages/home.aspx)
A deemed savings assumption, where site specific assumptions are not available would be as follows:

\[
\Delta kW = \frac{81.6}{8766} \times 1
\]

\[
\Delta kW \text{ default} = 0.00931 \text{ kW}
\]

**NATURAL GAS SAVINGS**

For homes with gas water heaters:

\[
\Delta \text{Therms} = \frac{(U \times A \times (T_{pre} - T_{post}) \times \text{Hours} \times \text{ISR})}{(100,000 \times \text{RE}_{\text{gas}})}
\]

Where

100,000 = Converts Btus to Therms (btu/Therm)

\[
\text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater}
\]

= 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:

\[
\Delta \text{Therms} = \frac{(U \times A \times (T_{pre} - T_{post}) \times \text{Hours} \times \text{ISR})}{\text{RE}_{\text{gas}}}
\]

= \(((0.083 \times 24.99) \times (135 - 120) \times 8766 \times 1.0) / (100,000 \times 0.78)\]

= 3.5 Therms

For Multi Family homes:

\[
\Delta \text{Therms} = \frac{(U \times A \times (T_{pre} - T_{post}) \times \text{Hours} \times \text{ISR})}{\text{RE}_{\text{gas}}}
\]

= \(((0.083 \times 24.99) \times (135 - 120) \times 8766 \times 1.0) / (100,000 \times 0.67)\]

= 4.1 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

#### ELECTRIC ENERGY SAVINGS
For electric DHW systems:

\[
\Delta \text{kWh} = \left( \frac{A_{\text{base}}}{R_{\text{base}} - A_{\text{insul}}/R_{\text{insul}}} \right) \cdot \Delta T \cdot \text{Hours} / (3412 \cdot \eta_{\text{DHW}})
\]

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.
The following table has default savings for various tank capacity and pre and post $R$-VALUES.

<table>
<thead>
<tr>
<th>Capacity (gal)</th>
<th>$R_{\text{base}}$</th>
<th>$R_{\text{insul}}$</th>
<th>$A_{\text{base}}$ (ft²)</th>
<th>$A_{\text{insul}}$ (ft²)</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>
</tr>
<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>
</tr>
<tr>
<td>30</td>
<td>12</td>
<td>20</td>
<td>19.16</td>
<td>20.94</td>
<td>86</td>
<td>0.0099</td>
</tr>
<tr>
<td>30</td>
<td>8</td>
<td>18</td>
<td>19.16</td>
<td>20.94</td>
<td>194</td>
<td>0.0221</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
<td>20</td>
<td>19.16</td>
<td>20.94</td>
<td>137</td>
<td>0.0156</td>
</tr>
<tr>
<td>30</td>
<td>12</td>
<td>22</td>
<td>19.16</td>
<td>20.94</td>
<td>101</td>
<td>0.0116</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
<td>16</td>
<td>23.18</td>
<td>25.31</td>
<td>207</td>
<td>0.0236</td>
</tr>
<tr>
<td>40</td>
<td>10</td>
<td>18</td>
<td>23.18</td>
<td>25.31</td>
<td>143</td>
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<tr>
<td>40</td>
<td>12</td>
<td>20</td>
<td>23.18</td>
<td>25.31</td>
<td>105</td>
<td>0.0120</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
<td>18</td>
<td>23.18</td>
<td>25.31</td>
<td>234</td>
<td>0.0268</td>
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<tr>
<td>40</td>
<td>10</td>
<td>20</td>
<td>23.18</td>
<td>25.31</td>
<td>165</td>
<td>0.0189</td>
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<tr>
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<td>12</td>
<td>22</td>
<td>23.18</td>
<td>25.31</td>
<td>123</td>
<td>0.0140</td>
</tr>
<tr>
<td>50</td>
<td>8</td>
<td>16</td>
<td>24.99</td>
<td>27.06</td>
<td>225</td>
<td>0.0257</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>18</td>
<td>24.99</td>
<td>27.06</td>
<td>157</td>
<td>0.0179</td>
</tr>
<tr>
<td>50</td>
<td>12</td>
<td>20</td>
<td>24.99</td>
<td>27.06</td>
<td>115</td>
<td>0.0131</td>
</tr>
<tr>
<td>50</td>
<td>8</td>
<td>18</td>
<td>24.99</td>
<td>27.06</td>
<td>255</td>
<td>0.0291</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>20</td>
<td>24.99</td>
<td>27.06</td>
<td>180</td>
<td>0.0206</td>
</tr>
<tr>
<td>50</td>
<td>12</td>
<td>22</td>
<td>24.99</td>
<td>27.06</td>
<td>134</td>
<td>0.0153</td>
</tr>
<tr>
<td>80</td>
<td>8</td>
<td>16</td>
<td>31.84</td>
<td>34.14</td>
<td>290</td>
<td>0.0331</td>
</tr>
<tr>
<td>80</td>
<td>10</td>
<td>18</td>
<td>31.84</td>
<td>34.14</td>
<td>202</td>
<td>0.0231</td>
</tr>
<tr>
<td>80</td>
<td>12</td>
<td>20</td>
<td>31.84</td>
<td>34.14</td>
<td>149</td>
<td>0.0170</td>
</tr>
<tr>
<td>80</td>
<td>8</td>
<td>18</td>
<td>31.84</td>
<td>34.14</td>
<td>328</td>
<td>0.0374</td>
</tr>
<tr>
<td>80</td>
<td>10</td>
<td>20</td>
<td>31.84</td>
<td>34.14</td>
<td>232</td>
<td>0.0265</td>
</tr>
<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>

$R_{\text{base}}$ = Overall thermal resistance coefficient prior to adding tank wrap (Hr-°F-ft²/BTU).

$R_{\text{insul}}$ = Overall thermal resistance coefficient after addition of tank wrap (Hr-°F-ft²/BTU).

$A_{\text{base}}$ = Surface area of storage tank prior to adding tank wrap (square feet).\[635\]

$A_{\text{insul}}$ = Surface area of storage tank after addition of tank wrap (square feet).\[636\]

Δ$T$ = Average temperature difference between tank water and outside air temperature (°F).

= 60°F \[637\]

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8766

3412 = Conversion from Btu to kWh

η$\text{DHW}$ = 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.

\[635\] 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 95F or lower).

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

**DEFINITION OF 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 $30642 plus $20 labor 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**

\[
\Delta \text{kWh} = \%\text{ElectricDHW} \times \left( (\text{GPM} \_\text{base} \_S \times \text{L}\_\text{showerdevice}) \times \text{Household} \times \text{SPCD} \times 365.25 \div \text{SPH} \right) \times \text{EPG}\_\text{electric} \times \text{ISR}
\]

Where:

- \%\text{ElectricDHW} = proportion of water heating supplied by electric resistance heating

<table>
<thead>
<tr>
<th>DHW fuel</th>
<th>%\text{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>

- GPM\_base\_S = Flow rate of the basecase showerhead, or actual if available

<table>
<thead>
<tr>
<th>Program</th>
<th>GPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct-install, device only</td>
<td>2.67</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</td>
</tr>
</tbody>
</table>

- L\_showerdevice = Hot water waste time avoided due to thermostatic restrictor valve

  = 0.89 minutes 648

- Household = Average number of people per household

<table>
<thead>
<tr>
<th>Household Unit Type 649</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
= 0.6\(^{653}\)

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(^{654})</td>
</tr>
<tr>
<td>Multi-Family</td>
<td>1.3(^{655})</td>
</tr>
<tr>
<td>Custom</td>
<td>Actual</td>
</tr>
</tbody>
</table>

EPG\_electric = Energy per gallon of hot water supplied by electric

\[
\text{EPG\_electric} = \frac{(8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp}))}{(\text{RE\_electric} \times 3412)}
\]

\[
\begin{align*}
\text{EPG\_electric} &= \frac{(8.33 \times 1.0 \times (101 - 54.1))}{(0.98 \times 3412)} \\
&= 0.117 \text{ kWh/gal}
\end{align*}
\]

8.33 = Specific weight of water (lbs/gallon)

1.0 = Heat Capacity of water (btu/lb-\(^\circ\))

ShowerTemp = Assumed temperature of water
= 101\(^{\circ}\) \(^{656}\)

SupplyTemp = Assumed temperature of water entering house
= 54.1\(^{\circ}\) \(^{657}\)

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>0.98(^{659})</td>
</tr>
<tr>
<td>Direct Install – Multi Family</td>
<td>0.95(^{660})</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


### Example

For example, a direct installed valve in a single-family home with electric DHW:

\[
\Delta k\text{Wh} = 1.0 \times (2.67 \times 0.89 \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.117 \times 0.98
\]

= 85 kWh

### Summer Coincident Peak Demand Savings

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

Where:

\[\Delta k\text{Wh} = \text{calculated value above}\]

\[\text{Hours} = \text{Annual electric DHW recovery hours for wasted showerhead use prevented by device}\]

\[= ((\text{GPM\_base\_S} \times \text{L\_showerdevice}) \times \text{Household} \times \text{SPCD} \times 365.25) \times 0.712^{661} / \text{GPH}\]

\[\text{GPH} = \text{Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.}\]

\[= 27.51\]

\[= 34.4 \text{ for SF Direct Install; 28.3 for MF Direct Install}\]

\[= 30.3 \text{ for SF Retrofit and TOS; 24.8 for MF Retrofit and TOS}\]

\[\text{CF} = \text{Coincidence Factor for electric load reduction}\]

\[= 0.0022^{662}\]

### Example

For example, a direct installed thermostatic restrictor device in a single family home with electric DHW where the number of showers is not known.

\[\Delta kW = 85.3/34.4 \times 0.0022\]

= 0.0055 kW

### Natural Gas Savings

\[\Delta \text{Therms} = \%\text{FossilDHW} \times ((\text{GPM\_base\_S} \times \text{L\_showerdevice}) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH}) \times \text{EPG\_gas} \times \text{ISR}\]

Where:

\[\%\text{FossilDHW} = \text{proportion of water heating supplied by Natural Gas heating}\]

---

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
<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>

\[ EPG_{\text{gas}} = \text{Energy per gallon of Hot water supplied by gas} \]
\[ = (8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{gas}} \times 100,000) \]
\[ = 0.00501 \text{ Therm/gal for SF homes} \]
\[ = 0.00583 \text{ Therm/gal for MF homes} \]

\[ \text{RE}_{\text{gas}} = \text{Recovery efficiency of gas water heater} \]
\[ = 78\% \text{ For SF homes}^{664} \]
\[ = 67\% \text{ For MF homes}^{665} \]

\[ 100,000 = \text{Converts Btus to Therms (btu/Therm)} \]

Other variables as defined above.

**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:

\[ \Delta \text{Therms} = 1.0 \times ((2.67 \times 0.89) \times 2.56 \times 0.6 \times 365.25 / 1.79) \times 0.00501 \times 0.98 \]
\[ = 3.7 \text{ therms} \]

**Water Impact Descriptions and Calculation**

\[ \Delta \text{gallons} = ((\text{GPM}_{\text{base_S}} \times \text{L}_{\text{showerdevice}}) \times \text{Household} \times \text{SPCD} \times 365.25 / \text{SPH}) \times \text{ISR} \]

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>
</thead>
<tbody>
<tr>
<td>12</td>
<td>2014, New York State Record of Revision to the TRM, Case 07-M-0548, June 19, 2014.</td>
</tr>
</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.\(^666\)

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%.\(^667\)

Algorithm

CALCULATION OF ENERGY SAVINGS

ELECTRIC ENERGY SAVINGS

\[
\Delta k\text{Wh} = \%\text{Electric DHW} \times \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \\
\times EPG_{\text{Electric}}
\]

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: Ore 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>
</tbody>
</table>

| Custom | Actual Occupancy or Number of Bedrooms675 |

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.


\[
= (8.33 \times 1.0 \times (\text{ShowerTemp} - \text{SupplyTemp})) / (\text{RE}_{\text{electric}} \times 3412)
\]
\[
= (8.33 \times 1.0 \times (101 - 54.1)) / (0.98 \times 3412)
\]
\[
= 0.117 \text{ kWh/gal}
\]

Based on default assumptions provided above, the savings for a single family home would be:

\[
\Delta \text{kWh} = \%\text{Electric DHW} \times \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \\
\times \text{EPG}_{\text{Electric}}
\]
\[
= 0.16 \times 1.93 \times (7.8 - 5.79) \times 2.56 \times 365.25 \times 0.6 \times 0.34 \times 0.117
\]
\[
= 13.9 \text{kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

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

Where:

\[
\Delta \text{kWh} \quad = \text{calculated value above}
\]
\[
\text{Hours} \quad = \text{Annual electric DHW recovery hours for showerhead use}
\]
\[
\text{GPH} \quad = \quad \text{Gallons per hour recovery of electric water heater calculated for 65.9F temp rise (120-54.1), 98% recovery efficiency, and typical 4.5kW electric resistance storage tank.}
\]
\[
\text{GPH} \quad = \quad 27.51
\]
\[
\text{CF} \quad = \text{Coincidence Factor for electric load reduction}
\]
\[
\text{CF} \quad = \quad 0.0278^{678}
\]

Based on default assumptions provided above, the savings for a single family home would be:

\[
\Delta \text{W} \quad = \Delta \text{kWh/Hours} \times \text{CF}
\]
\[
= 0.0013 \text{ kW}
\]

**NATURAL GAS SAVINGS**

\[
\Delta \text{Therms} = \%\text{FossilDHW} \times \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \\
\times \text{EPG}_{\text{Gas}}
\]
\[
\%\text{FossilDHW} \quad = \text{Proportion of water heating supplied by electric resistance heating}
\]

<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%^{679}</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*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

^{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:

\[ \Delta \text{Gallons} = \text{GPM} \times (L_{\text{base}} - L_{\text{timer}}) \times \text{Household} \times \text{Days/yr} \times \text{SPCD} \times \text{UsageFactor} \]

\[ = 1.93 \times (7.8 - 5.79) \times 2.56 \times 365.25 \times 0.6 \times 0.34 \]
\[ = 740.0 \text{ gallons} \]

**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.

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.

---

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\textsuperscript{684}.

For the Direct Install measure, the full cost of $2.45 per bulb should be used, plus $5 labor cost\textsuperscript{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\textsuperscript{686} and 7.4\% for Residential Direct Install\textsuperscript{687}.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

$$\Delta k\text{Wh} = ((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times (1-\text{Leakage}) \times \text{Hours} \times \text{WHFe}$$

Where:

\text{WattsBase} = \text{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} = \text{Actual wattage of CFL purchased / installed}

\textsuperscript{684} Based upon field data collected by CLEAResult and provided by ComEd. See ComEd Pricing Projections 06302016.xlsx for analysis.

\textsuperscript{685} Based on 15 minutes at $20 an hour. Includes some portion of travel time to site.

\textsuperscript{686} Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{687} Based on lighting logger study conducted as part of the PYS/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></td>
<td></td>
<td></td>
<td>83%</td>
</tr>
<tr>
<td>School Kits(^{693})</td>
<td></td>
<td></td>
<td></td>
<td>86%</td>
</tr>
<tr>
<td>Direct Mail Kits(^{694})</td>
<td></td>
<td></td>
<td></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 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).
**5.5.1 Compact Fluorescent Lamp (CFL)**

**Hours** = Average hours of use per year

<table>
<thead>
<tr>
<th>Program Delivery</th>
<th>Installation Location</th>
<th>Hours</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>

**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>
<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 $1 + (0.66 \times \frac{0.27}{2.8})$). 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 $(-0.02 \times \text{SEER}) + (1.12 \times \text{SEER})$ (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 $= \frac{\text{EER}}{3.412} = 2.8\text{COP}$ 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).
For example, for a 14W CFL (60W standard incandescent and 43W EISA qualified incandescent/halogen):

\[
\Delta kWH_{1\text{st year installs}} = \frac{(43 - 14)}{1000} \times 0.765 \times 847 \times 1.06 = 19.9 \text{ kWh}
\]

\[
\Delta kWH_{2\text{nd year installs}} = \frac{(43 - 14)}{1000} \times 0.116 \times 847 \times 1.06 = 3.0 \text{ kWh}
\]

\[
\Delta kWH_{3\text{rd year installs}} = \frac{(43 - 14)}{1000} \times 0.099 \times 847 \times 1.06 = 2.6 \text{ kWh}
\]

HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[
\Delta kWH = - \left( \frac{(WattsBase - WattsEE)}{1000} \times ISR \times Hours \times HF \right) / \etaHeat
\]

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

\etaHeat = Efficiency in COP of Heating equipment

= actual. If not available use:

\[
\text{COP}_{\text{Heat}} = \frac{\text{HSPF}}{3.413} \times 0.85
\]

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP_{\text{Heat}} (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>

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

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.

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.

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:

\[
\Delta kWh_{1st\ year} = - (((43 - 14) / 1000) * 0.765 \cdot 759 \cdot 0.49) / 2.0
\]
\[
= - 4.2 \text{ kWh}
\]

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**

\[\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) \cdot \text{ISR} \cdot \text{WHFd} \cdot \text{CF}\]

Where:

- \(\text{WHFd}\) = Waste heat factor for demand to account for cooling savings from efficient lighting.
- \(\text{CF}\) = Summer Peak Coincidence Factor for measure.

<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>

<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:

\[
\Delta kW = ((43 - 14) / 1000) \cdot 0.765 \cdot 1.11 \cdot 0.071
\]
\[
= 0.0017 \text{ kW}
\]

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

---

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):

\[ \Delta \text{Therms} = \frac{- (\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412 \times \eta_{\text{Heat}} \]

Where:

- \( \text{HF} \) = Heating Factor or percentage of light savings that must be heated
  - 49\% 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\% for typical systems

For example, a 14 standard CFL is purchased and installed in a home:

\[ \Delta \text{Therms} = \frac{- ((43 - 14) / 1000) \times 0.765 \times 759 \times 0.49 \times 0.03412}{0.7} \]

\[ = -0.40 \text{ Therms} \]

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

The O&M assumptions that should be used in cost effectiveness calculations are provided below:

\[ \text{Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:} \]

\[ (0.24\times0.92) + (0.76\times0.8) \times (1-0.15) = 0.70 \]

---

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:
Program Delivery | Installation Location | Replacement Period (years)$^{712}$ | Replacement Cost$^{713}$
---|---|---|---
Retail (Time of Sale) and Efficiency Kits | Residential Interior and in-unit Multi Family | 1.3 | 
Exterior | 0.4 | 
Unknown | 1.2 | $1.25
Direct Install | Residential Interior and in-unit Multi Family | 1.3 | 
Exterior | 0.4 | 

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.

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 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.

**DEEMED MEASURE COST**

For the Retail (Time of Sale) measure, the incremental capital cost for this measure is $5.

For the Direct Install measure, the full cost of $8.50 should be used plus $5 labor 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

<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>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>

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta kHz = \frac{(WattsBase - WattsEE)}{1000} \times ISR \times (1 - \text{Leakage}) \times \text{Hours} \times \text{WHFe}
\]

Where:

- **WattsBase** = Actual wattage equivalent of incandescent specialty bulb, use the tables below to obtain the incandescent bulb equivalent wattage; use 60W if unknown.

---

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><strong>Standard Spirals &gt;=2601</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<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><strong>3-Way</strong></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></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><strong>Globe (medium and intermediate bases less than 750 lumens)</strong></td>
<td></td>
<td></td>
<td></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>120</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><strong>Decorative (Shapes B, BA, C, CA, DC, F, G, medium and intermediate bases less than 750 lumens)</strong></td>
<td></td>
<td></td>
<td></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><strong>Globe (candelabra bases less than 1050 lumens)</strong></td>
<td></td>
<td></td>
<td></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><strong>Decorative (Shapes B, BA, C, CA, DC, F, G, candelabra bases less than 1050 lumens)</strong></td>
<td></td>
<td></td>
<td></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.\(^{724}\)

For Directional R, BR, and ER lamp types\(^{725}\):

<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>

\(^{724}\) From pg 10 of the Energy Star Specification for lamps v1.1

\(^{725}\) From pg 11 of the Energy Star Specification for lamps v1.1
Bulb Type  | Lower Lumen Range | Upper Lumen Range | WattsBase |
---|---|---|---|
*R, BR, and ER with medium screw bases w/ diameter <=2.25" | 2175 2624 3000 | 150 175 200 | 400 450 650 |
*ER30, BR30, BR40, or ER40 | 400 450 500 | 40 45 50 | 449 499 649 |
*BR30, BR40, or ER40 | 450 500 650 | 40 50 65 | 499 649 1199 |
*R20 | 450 500 650 | 40 50 65 | 719 649 1419 |
*All reflector lamps below lumen ranges specified above | 300 300 | 20 30 | 299 299 |

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.\(^{227}\)

\[
\text{WattsBase} = 375.1 - 4.355(D) - \sqrt{227.800 - 937.9(D) - 0.9903(D^2)} - 1479(BA) - 12.02(D \times BA) + 14.69(BA^2) - 16.720 \times \ln(CBCP)
\]

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>

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.
### Table 5.5.2: 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>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</td>
<td>749</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>1049</td>
<td>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 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%</td>
<td>5.4%</td>
<td>4.6%</td>
<td>98.0%</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency Kits</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFO Distribution</td>
<td>59%</td>
<td>13%</td>
<td>11%</td>
<td>83%</td>
</tr>
<tr>
<td>School Kits</td>
<td>61%</td>
<td>13%</td>
<td>11%</td>
<td>86%</td>
</tr>
<tr>
<td>Direct Mail Kits</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

---


729 1st 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.

730 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.

731 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.

732 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.

733 Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions.

734 Kits provided free to students through school, with education program. Consistent with Standard CFL assumptions.

735 Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions.
deemed appropriate\textsuperscript{736} of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Determined through evaluation

or use deemed assumptions below\textsuperscript{737}:

\begin{itemize}
  \item ComEd: 2.1%
  \item Ameren: 13.1%
  \item All other programs = 0
\end{itemize}

Hours = Average hours of use per year, varies by bulb type as presented below:\textsuperscript{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>

\textbf{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 \textsuperscript{739}</td>
</tr>
</tbody>
</table>

\textsuperscript{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.

\textsuperscript{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).

\textsuperscript{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.

\textsuperscript{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.

### HEATING PENALTY

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[
\Delta kWH_{1st \ year \ installs} = \frac{(WattsBase - WattsEE)}{1000} \times 0.823 \times 850 \times 1.06
\]

= 34.9 kWh

\[
\Delta kWH_{2nd \ year \ installs} = \frac{(43 - 13)}{1000} \times 0.085 \times 850 \times 1.06
\]

= 2.3 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 kWh

Note: delta watts is equivalent to install year. Here we assume no change in hours assumption.

### Notes

- **Table Location**

<table>
<thead>
<tr>
<th>Bulb Location</th>
<th>WHFe</th>
</tr>
</thead>
<tbody>
<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>

**Region, Divisions, and States, 2009 from Energy Information Administration”, 2009 Residential Energy Consumption Survey**

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\textsuperscript{743}:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP\textsubscript{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\textsuperscript{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):

\[
\Delta k\text{Wh}_{\text{1st year}} = - \left( \frac{(60 - 15)}{1000} \right) \times 0.823 \times 639 \times 0.49 / 2.0
\]

\[
= - 5.8 \text{ kWh}
\]

Second and third year savings should be calculated using the appropriate ISR.

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times \text{WHFd} \times \text{CF}
\]

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\textsuperscript{745}</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07\textsuperscript{746}</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\[
\text{CF} = \text{Summer Peak Coincidence Factor for measure. Coincidence factors by bulb types are presented below}\textsuperscript{747}
\]

\textsuperscript{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. Defaults provided assume 15\% duct loss for heat pumps.

\textsuperscript{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.

\textsuperscript{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.

\textsuperscript{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.

\textsuperscript{747} Based on lighting logger study conducted as part of the PY5/6 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>0.078</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>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>

#### Natural Gas Savings

Heating Penalty if Natural Gas heated home (or if heating fuel is unknown):

\[
\Delta \text{Therms} \approx \frac{-(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412 \times \eta_{\text{Heat}}
\]

Where:

- \( \text{HF} \) = Heating Factor or percentage of light savings that must be heated
- \( \eta_{\text{Heat}} \) = Efficiency of heating system
- \( 0.03412 \) = Converts kWh to Therms
- \( 49\% \) \( ^{751} \) for interior or unknown location
- \( 0\% \) for exterior location

#### Example

For example, a 15W specialty CFL replacing a 60W incandescent specialty bulb:

\[
\Delta k\text{W}_{1\text{st year}} = \frac{(60 - 15)}{1000} \times 0.823 \times 1.11 \times 0.081 = 0.003 \text{ kW}
\]

Second and third year savings should be calculated using the appropriate ISR.

---

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:

\[
\Delta \text{Therms} = - \frac{(60 - 15)}{1000} \times 0.823 \times 639 \times 0.49 \times 0.03412}{0.7} \\
= -0.57 \text{ Therms}
\]

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\(^7\); baseline replacement cost is assumed to be $3.5\(^7\).

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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market or geographical area then that should be used.)

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:

\[(0.24 \times 0.92) + (0.76 \times 0.8) \times (1-0.15) = 0.70\]

\(^7\) Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32

\(^7\) 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.\(^{755}\)

**DEEMED MEASURE COST**

The incremental cost for this measure is assumed to be $5.\(^{756}\)

**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.\(^{757}\)

---

**Algorithm**

**CALCULATION OF SAVINGS**

**ELECTRIC ENERGY SAVINGS**

\[
\Delta \text{kWh} = \left( \frac{\Delta \text{Watts}}{1000} \right) \times \text{ISR} \times (1-\text{Leakage}) \times \text{HOURS} \times \text{WHFe}
\]

Where:

\[
\Delta \text{Watts} = \text{Average delta watts per purchased ENERGY STAR torchiere} = 115.8 \quad \text{\(^{758}\)}
\]

---


\(^{756}\) DEER 2008 Database Technology and Measure Cost Data (www.deeresources.com) and consistent with Efficiency Vermont TRM.

\(^{757}\) Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

\(^{758}\) 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 \(^7\)

**Leakage**  
= Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate\(^6\)) of the Utility Jurisdiction.

KITS programs = Determined through evaluation  
Upstream (TOS) Lighting programs = Determined through evaluation  
or use deemed assumptions below\(^1\):  

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ComEd:</td>
<td>2.1%</td>
</tr>
<tr>
<td>Ameren:</td>
<td>13.1%</td>
</tr>
<tr>
<td>All other programs</td>
<td>0</td>
</tr>
</tbody>
</table>

**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)(^2)</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 (^3)</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.04 (^4)</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

For single family buildings:

\[
\Delta \text{kWh} = \left( \frac{115.8}{1000} \right) \times 0.86 \times 1095 \times 1.06 \\
= 116 \text{kWh}
\]

---

\(^7\) Nexus Market Research, RLW Analytics “Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs” table 6-3 on p63 indicates that 86% torchieres were installed in year one.  

\(^6\) 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.

\(^1\) 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).

\(^2\) Nexus Market Research, “Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs”, Final Report, October 1, 2004, p. 43 (Table 4-9)

\(^3\) 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)  

\(^4\) 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:
\[ \Delta kWh = \left( \frac{115.8}{1000} \right) \times 0.86 \times 1095 \times 1.04 \]
\[ = 113 kWh \]

**Heating Penalty**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):
\[ \Delta kWh = - \left( \frac{\Delta Watts}{1000} \right) \times ISR \times \text{HOURS} \times \text{HF} / \eta_{\text{Heat}} \]

Where:
- HF = Heating Factor or percentage of light savings that must be heated
  - 49% for interior or unknown location
- \( \eta_{\text{Heat}} \) = Efficiency in COP of Heating equipment
  - Actual. If not available use defaults provided below:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \text{COP}_{\text{Heat}} ) (COP Estimate) = ( \frac{\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>
<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>

For example, an ES torchiere installed in a house with a 2016 heat pump:
\[ \Delta kWh = - \left( \frac{\left( \frac{115.8}{1000} \right)}{1000} \right) \times 0.86 \times 1095 \times 0.49 / 2.04 \]
\[ = -26.2 kWh \]

**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.
### ENERGY STAR Torchiere

**Bulb Location** | **WHFd**
---|---
Interior single family or unknown location | 1.11<sup>769</sup>
Multi family in unit | 1.07<sup>770</sup>
Exterior or uncooled location | 1.0

\[
CF = \text{Summer Peak Coincidence Factor for measure}
\]

**Bulb Location** | **CF<sup>771</sup>**
---|---
Interior single family or Multi family in unit | 7.1\%<sup>771</sup>
Unknown location | 8.1\%<sup>771</sup>

For single family and multi-family in unit buildings:

\[
\Delta kW = \frac{(115.8 / 1000) \times 0.86 \times 1.11 \times 0.071}{0.008 kW}
\]

For unknown location:

\[
\Delta kW = \frac{(115.8 / 1000) \times 0.86 \times 1.07 \times 0.081}{0.009 kW}
\]

### Natural Gas Savings

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

\[
\Delta \text{Therms}_{\text{WH}} = - \left( \frac{\Delta \text{Watts}}{1000} \right) \times \text{ISR} \times \text{HOURS} \times 0.03412 \times \text{HF} / \eta_{\text{Heat}}
\]

Where:

- \(\Delta \text{Therms}_{\text{WH}}\) = gross customer annual heating fuel increased usage for the measure from the reduction in lighting heat in therms.
- 0.03412 = conversion from kWh to therms
- HF = Heating Factor or percentage of light savings that must be heated
  - 49\%<sup>772</sup>
- \(\eta_{\text{Heat}}\) = average heating system efficiency
  - 70\%<sup>773</sup>

<sup>769</sup> 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.

<sup>770</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).

<sup>771</sup> Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

<sup>772</sup> 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.

<sup>773</sup> 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 are actually in service and so should be multiplied by the appropriate ISR.

**MEASURE CODE: RS-LTG-ESTO-V04-180101**

**REVIEW DEADLINE: 1/1/2020**

---

\(^{774}\) 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\textsuperscript{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\textsuperscript{777}.

DEEMED MEASURE COST

The incremental cost for an exterior fixture is assumed to be $32\textsuperscript{778}.

LOADSHAPE

Loadshape R07 - Residential Outdoor Lighting


\textsuperscript{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.

\textsuperscript{778} ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for exterior fixture (http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?4349-303e=&b6b3-3efd&b6b3-3efd)
COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 27.3%\textsuperscript{779}.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta \text{kWh} = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times (1 - \text{Leakage}) \times \text{Hours} \]

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\textsuperscript{780}</td>
<td>5.7%</td>
<td>4.8%</td>
<td>98.0\textsuperscript{781}</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9\textsuperscript{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

\textsuperscript{779} Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{780} 1\textsuperscript{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 the each year’s survey.

\textsuperscript{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\textsuperscript{nd} and 3\textsuperscript{rd} year installations should be counted as part of those future program year savings.

\textsuperscript{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\textsuperscript{783}) of the Utility Jurisdiction.

KITS programs = Determined through evaluation
Upstream (TOS) Lighting programs = Determined through evaluation
or use deemed assumptions below\textsuperscript{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)\textsuperscript{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.

1. **Year 1 (Purchase Year) installs:** Characterized using assumptions provided above or evaluated assumptions if available.
2. **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 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen).

\[
\Delta kWH_{1\text{st year installs}} = \frac{(86 - 28)}{1000} \times 0.875 \times 2475 = 125.6 \text{ kWh}
\]

\[
\Delta kWH_{2\text{nd year installs}} = \frac{(86 - 28)}{1000} \times 0.057 \times 2475 = 8.2 \text{ kWh}
\]

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

\[
\Delta kWH_{3\text{rd year installs}} = \frac{(86 - 28)}{1000} \times 0.048 \times 2475 = 6.9 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{CF}
\]

Where:

\textsuperscript{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.

\textsuperscript{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)).

\textsuperscript{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

<table>
<thead>
<tr>
<th>Measure Code</th>
<th>RS-LRG-EFOX-V06-180101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review Deadline</td>
<td>1/1/2020</td>
</tr>
</tbody>
</table>

Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

786 Based on lighting logger study conducted as part of the PY5/6 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\(^789\). 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\(^790\).

**DEEMED MEASURE COST**

The incremental cost for an interior fixture is assumed to be $32\(^791\).

**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.

\(^791\) ENERGY STAR Qualified Lighting Savings Calculator default incremental cost input for interior fixture (http://www.energystar.gov/buildings/sites/default/uploads/files/light_fixture_ceiling_fan_calculator.xlsx?4349-303e=&b6b3-3efd&b6b3-3efd)
COINCIDENCE FACTOR

The summer peak coincidence factor is assumed to be 7.1%\textsuperscript{792} for Residential and in-unit Multi Family bulbs.

\textbf{Algorithm}

\textbf{CALCULATION OF SAVINGS}

\textbf{ELECTRIC ENERGY SAVINGS}

\[ \Delta k\text{Wh} = \left( \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \right) \times \text{ISR} \times (1-\text{Leakage}) \times \text{Hours} \times \text{WHFe} \]

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\textsuperscript{793}</td>
<td>5.7%</td>
<td>4.8%</td>
<td>98.0\textsuperscript{794}</td>
</tr>
<tr>
<td>Direct Install</td>
<td>96.9\textsuperscript{795}</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{792} Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{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 each year’s survey.

\textsuperscript{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.

\textsuperscript{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:

<table>
<thead>
<tr>
<th>ComEd</th>
<th>1.05%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ameren</td>
<td>6.55%</td>
</tr>
</tbody>
</table>

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).
HEATING PENALTY

If electric heated building:

\[ \Delta \text{kWh} = \frac{-(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{Hours} \times \text{HF} \times \frac{1}{\eta_{\text{Heat}}} \]

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:\n
<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \text{COP}_{\text{Heat}} ) (COP Estimate) = ( \frac{\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</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. Defaults 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, for a 2 x 14W pin based CFL fixture (43W EISA qualified incandescent/halogen):

\[ \Delta \text{kWh}_{1\text{st year installs}} = \frac{(86 - 28)}{1000} \times 0.875 \times 759 \times 1.06 = 40.8 \text{ kWh} \]
\[ \Delta \text{kWh}_{2\text{nd year installs}} = \frac{(86 - 28)}{1000} \times 0.057 \times 759 \times 1.06 = 2.7 \text{ kWh} \]
\[ \Delta \text{kWh}_{3\text{rd year installs}} = \frac{(86 - 28)}{1000} \times 0.048 \times 759 \times 1.06 = 2.2 \text{ kWh} \]
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:

\[ \Delta k\text{Wh}_{1\text{st year}} = -[((86 - 28) / 1000) * 0.875 * 759 * 0.49] / 2.0 \]
\[ = -9.4 \text{ kWh} \]

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

\[ \Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{WHFd} * \text{CF} \]

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\textsuperscript{805}</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07\textsuperscript{806}</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>Bulb Location</th>
<th>CF\textsuperscript{807}</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:

\[ \Delta kW_{1\text{st year}} = ((86-28) / 1000) * 0.875 * 1.11 * 0.071 \]
\[ = 0.004 \text{ kW} \]

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

\[ \Delta \text{Therms} = -((\text{WattsBase} - \text{WattsEE}) / 1000) * \text{ISR} * \text{Hours} * \text{HF} * 0.03412) / \eta\text{Heat} \]

Where:

\[ \text{HF} = \text{Heating Factor or percentage of light savings that must be heated} \]

\textsuperscript{805} The value is estimated at 1.11 \((\text{calculated as } 1 + (0.66 * 0.466 / 2.8))\). 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{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).

\textsuperscript{807} Based on lighting logger study conducted as part of the PYS/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{808} Negative value because this is an increase in heating consumption due to the efficient lighting.
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.

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:

\[ (0.24 \times 0.92) + (0.76 \times 0.8) \times (1 - 0.15) = 0.70 \]

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-IFIX-V06-180101

REVIEW DEADLINE: 1/1/2020
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>$5.18</td>
<td>$1.65</td>
<td></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>$1.74</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.xlsx) 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.818

<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

**ELECTRIC ENERGY SAVINGS**

\[
\Delta kWh = \frac{(WattsBase - WattsEE) \times 1000 \times ISR \times (1-Leakage) \times Hours \times WHFe}{1000000}
\]

Where:

- \(WattsBase\) = 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>WattsBase</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
<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>Globe</td>
<td>90</td>
<td>179</td>
<td>10</td>
</tr>
<tr>
<td>Decorative</td>
<td>70</td>
<td>89</td>
<td>10</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>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</td>
<td>180</td>
<td>249</td>
<td>15</td>
</tr>
<tr>
<td>Decorative</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>500</td>
<td>1049</td>
<td>60</td>
</tr>
</tbody>
</table>

**Directional Lamps**

For Directional R, BR, and ER lamp types:\n
<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></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/ diameter &lt;=2.25&quot;</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.\(^{822}\) 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.\(^{823}\)

\[
\text{Wattsbase} = 375.1 - 4.355(D) - \sqrt{227,800 - 937.9(D) - 0.9903(D^2) - 1479(BA) - 12.02(D \times BA) + 14.69(BA^2) - 16,720 \times \ln(CBCP)}
\]

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>

\(^{822}\) [http://energystar.supportportal.com/link/portal/23002/23018/Article/32655/]

\(^{823}\) 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</td>
<td>749</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>750</td>
<td>1049</td>
<td>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></td>
</tr>
<tr>
<td></td>
<td>All other lamps</td>
<td>93.5%825</td>
<td>2.4%</td>
<td>2.1%</td>
<td>98.0%826</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:
\[
\Delta kWh = \frac{(45 - 13)}{1000} \times 0.935 \times 861 \times 1.06
\]
\[
= 27.3 \text{ kWh}
\]
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):
\[
\Delta kWh^{833} = - \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \times \text{ISR} \times \text{Hours} \times \text{HF} \right) / \eta_{\text{Heat}}
\]
Where:

- HF = Heating Factor or percentage of light savings that must be heated
  - 49%\textsuperscript{834} for interior or unknown location
  - 0% for exterior location

- \eta_{\text{Heat}} = Efficiency in COP of Heating equipment
  = Actual. If not available use: \textsuperscript{835}:

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>COP\textsubscript{HEAT} (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\textsuperscript{836}</td>
<td>N/A</td>
<td>N/A</td>
<td>1.28</td>
</tr>
</tbody>
</table>

\textsuperscript{833} Negative value because this is an increase in heating consumption due to the efficient lighting.

\textsuperscript{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.

\textsuperscript{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.

\textsuperscript{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:

\[
\Delta \text{kWh} = - ((45 - 13) / 1000) \times 0.935 \times 861 \times 0.49 / 2.04 \\
= - 6.19 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[
\Delta kW = ((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times \text{WHFd} \times \text{CF}
\]

Where:

- **WHFd** = Waste heat factor for demand to account for cooling savings from efficient lighting.

<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{837}</td>
</tr>
<tr>
<td>Multi family in unit</td>
<td>1.07\textsuperscript{838}</td>
</tr>
<tr>
<td>Exterior or uncooled location</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- **CF** = Summer Peak Coincidence Factor for measure, see above for values. \textsuperscript{839}

<table>
<thead>
<tr>
<th>Bulb Type</th>
<th>Peak CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three-way</td>
<td>0.078\textsuperscript{840}</td>
</tr>
<tr>
<td>Dimmable</td>
<td>0.078\textsuperscript{841}</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

\textsuperscript{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.

\textsuperscript{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).

\textsuperscript{839} Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{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.

\textsuperscript{841} Ibid
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:

$$\Delta kW = ((45 - 13) / 1000) * 0.935 * 1.11 * 0.091$$

$$= 0.0030 kW$$

**NATURAL GAS SAVINGS**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

$$\Delta \text{therms} = - \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{ISR} \times \text{Hours} \times \text{HF} \times 0.03412 / \eta_{\text{Heat}}$$

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 with gas heating at 70% total efficiency:

$$\Delta \text{therms} = - \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times 0.935 \times 861 \times 0.49 \times 0.03412 / 0.70$$

$$= - 0.62 \text{ therms}$$

**WATER IMPACT DESCRIPTIONS AND CALCULATION**

N/A

**DEEMED O&M COST ADJUSTMENT CALCULATION**

For those bulbs 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 year844; 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:

$$0.24 \times 0.92 + 0.76 \times 0.8 \times (1 - 0.15) = 0.70$$

844 Assuming 1000 hour rated life for incandescent bulb: 1000/759 = 1.32
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.\(^{845}\)

\[
\begin{array}{|c|c|c|}
\hline
\text{EISA Compliant Incandescent/Halogen (Decorative/Globe)} & \text{Specialty CFL} \\
\hline
2017 & $1.74 & N/A \\
2018 & $1.74 & N/A \\
2019 & $1.74 & N/A \\
2020 & N/A & $3.40^{846} \\
\hline
\end{array}
\]

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.46% are presented below.\(^{848}\)

<table>
<thead>
<tr>
<th>Location</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>Interior and Unknown</td>
<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>
<td>$2.86</td>
<td>$0.29</td>
</tr>
<tr>
<td>Exterior</td>
<td></td>
<td>$5.96</td>
<td>$0.61</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.

\(^{845}\) 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.

DEEMED MEASURE COST

The incremental cost for this measure is assumed to be $30.

LOADSHAPE

Loadshape C53 - Flat

COINCIDENCE FACTOR

The summer peak coincidence factor for this measure is assumed to be 100%.

Algorithm

CALCULATION OF SAVINGS

ELECTRIC ENERGY SAVINGS

\[ \Delta kWH = \left( \frac{\text{WattsBase} - \text{WattsEE}}{1000} \right) \times \text{HOURS} \times \text{WHF} \]

Where:

\[ \text{WattsBase} = \text{Actual wattage if known, if unknown assume the following:} \]

---


850 NYSERDA Deemed Savings Database, Labor cost assumes 25 minutes @ $18/hr.

851 Assuming continuous operation of an LED exit sign, the Summer Peak Coincidence Factor is assumed to equal 1.0.
### Baseline Type

<table>
<thead>
<tr>
<th>Baseline Type</th>
<th>WattsBase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>35W&lt;sup&gt;852&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>11W&lt;sup&gt;853&lt;/sup&gt;</td>
</tr>
<tr>
<td>Unknown (e.g. time of sale)</td>
<td>11W</td>
</tr>
</tbody>
</table>

WattsEE = Actual wattage if known, if unknown assume 2W<sup>854</sup>

HOURS = Annual operating hours

= 8766

WHF<sub>e</sub> = Waste heat factor for energy; accounts for cooling savings from efficient lighting.

= 1.04<sup>855</sup> for multi family buildings

Default if replacing incandescent fixture

\[
\Delta kWh = \frac{(35 - 2) / 1000 \times 8766 \times 1.04}{\eta_{\text{Heat}}}
\]

= 301 kWh

Default if replacing fluorescent fixture

\[
\Delta kWh = \frac{(11 - 2) / 1000 \times 8766 \times 1.04}{\eta_{\text{Heat}}}
\]

= 82 kWh

**HEATING PENALTY**

If electric heated building (if heating fuel is unknown assume gas, see Natural Gas section):

\[
\Delta kWh = \frac{-(\text{WattsBase} - \text{WattsEE}) / 1000 \times \text{Hours} \times \text{HF}}{\eta_{\text{Heat}}}
\]

Where:

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

= 49%<sup>857</sup>

\eta_{\text{Heat}} = Efficiency in COP of Heating equipment

= Actual. If not available use: <sup>858</sup>

---

<sup>852</sup> Based on review of available product.


<sup>855</sup> 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)

<sup>856</sup> Negative value because this is an increase in heating consumption due to the efficient lighting.

<sup>857</sup> 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.

<sup>858</sup> 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: $\Delta kWH = -\frac{(35 - 2)/1000 \times 8766 \times 0.49}{2}$
  
  $= -71$ kWh

- If fluorescent fixture: $\Delta kWH = -\frac{(11 - 2)/1000 \times 8766 \times 0.49}{2}$
  
  $= -19$ kWh

#### SUMMER COINCIDENT PEAK DEMAND SAVINGS

$$\Delta kW = \frac{(WattsBase - WattsEE) \times WHF_d \times CF}{1000}$$

Where:

- $WHF_d$ = Waste heat factor for demand to account for cooling savings from efficient lighting. The cooling savings are only added to the summer peak savings.
  
  $= 1.07^{860}$ for multi family buildings

- $CF$ = Summer Peak Coincidence Factor for measure
  
  $= 1.0$

  Default if incandescent fixture

  $\Delta kW = \frac{(35 - 2)/1000 \times 1.07 \times 1.0}{2}$

  $= 0.035$ kW

  Default if fluorescent fixture

  $\Delta kW = \frac{(11 - 2)/1000 \times 1.07 \times 1.0}{2}$

  $= 0.0096$ kW

#### NATURAL GAS SAVINGS

Heating penalty if Natural Gas heated building, or if heating fuel is unknown.

$$\Delta$therms = - \frac{((WattsBase - WattsEE) \times Hours \times HF \times 0.03412)}{\eta_{Heat}}$$

---

<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.
HF = 49% 861

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.
ηHeat = 0.70 862

Other factors as defined above

Default if incandescent fixture

\[
\text{Δtherms} = -\left(\frac{(35 - 2)}{1000}\right) \times 8766 \times 0.49 \times 0.03412 / 0.70
\]
\[
= -6.9 \text{ therms}
\]

Default if fluorescent fixture

\[
\text{Δtherms} = -\left(\frac{(11 - 2)}{1000}\right) \times 8766 \times 0.49 \times 0.03412 / 0.70
\]
\[
= -1.9 \text{ therms}
\]

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>Baseline Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp</td>
<td>Cost</td>
</tr>
<tr>
<td>Lamp</td>
<td>$7.00</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:
\[(0.24 \times 0.92) + (0.76 \times 0.8) \times (1 - 0.15) = 0.70\]
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\(^{865}\).

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](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\(^{866}\) for exterior application. For all other applications, lifetimes are capped at 10 years\(^{867}\).

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\(^{868}\).

**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\(^{869}\):

<table>
<thead>
<tr>
<th>Year</th>
<th>EISA Compliant Halogen</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>$1.25</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 ‘RESvCI Split_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.
LED Screw Based Omnidirectional Bulbs

### 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**

\[
\Delta kWh = \left(\frac{Watts_{base} - Watts_{EE}}{1000}\right) \times ISR \times (1 - \text{Leakage}) \times \text{Hours} \times \text{WHF}_e
\]

Where:

- **Watts\text{\textsubscript{base}}** = Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.
- **Watts\text{\textsubscript{EE}}** = Actual wattage of LED purchased / installed. If unknown, use default provided below.

### LED New and Baseline Assumptions Table

<table>
<thead>
<tr>
<th>Minimum Lumens</th>
<th>Maximum Lumens</th>
<th>Lumens used to calculate LED Wattage (midpoint)</th>
<th>LED Wattage \text{\textsuperscript{871}} (Watts\text{\textsubscript{EE}})</th>
<th>Baseline 2014-2019 (Watts\text{\textsubscript{Base}})</th>
<th>Delta Watts 2014-2019 (Watts\text{\textsubscript{EE}})</th>
<th>Baseline Post EISA 2020 requirement\text{\textsuperscript{872}} (Watts\text{\textsubscript{Base}})</th>
<th>Delta Watts Post 2020 (Watts\text{\textsubscript{EE}})</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.

\textsuperscript{870} Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation.

\textsuperscript{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.

\textsuperscript{872} Calculated as 45 lm/W for all EISA non-exempt bulbs.
### 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>CFL Distribution(^{877}) 59%</td>
<td>13%</td>
<td>11%</td>
<td>83%</td>
</tr>
<tr>
<td></td>
<td>School Kits(^{878}) 61%</td>
<td>13%</td>
<td>11%</td>
<td>86%</td>
</tr>
<tr>
<td></td>
<td>Direct Mail Kits(^{879}) 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 PY6,7,8 and 8 for Ameren (see ‘IL Leakage Rates_112016.xls’ for more information).
### 5.5.8 LED Screw Based Omnidirectional Bulbs

<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 = 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&lt;sup&gt;884&lt;/sup&gt;</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 PYS6 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:

\[
\Delta \text{kWh} = ((29 - 6.7) / 1000) \times 847 \times 1.06 \times 0.899 \\
= 18.0 \text{ kWh}
\]

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 \((18.0 \times 0.226 =) 4.1 \text{ kWh}\) 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.

\[
\Delta \text{kWh}_{1\text{st year installs}} = ((29 - 6.7)/1000) \times 847 \times 1.06 \times 0.899 \\
= 18.0 \text{ kWh}
\]

\[
\Delta \text{kWh}_{2\text{nd year installs}} = ((29 - 8)/1000) \times 847 \times 1.06 \times 0.043 \\
= 0.9 \text{ kWh}
\]

Note: Here we assume no change in hours assumption. NTG value from Purchase year applied.

**Heating Penalty**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

\[
\Delta \text{kWh}^{885} = - (((\text{WattsBase} - \text{WattsEE}) / 1000) \times \text{ISR} \times \text{ Hours} \times \text{ HF}) / \eta\text{Heat}
\]

Where:

- \( \text{HF} \) = 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_{Heat} = Efficiency in COP of Heating equipment
= 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)</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):

$$\Delta k\text{Wh}_{1\text{st year}} = -\left(\frac{(29-6.7)}{1000} \times 0.899 \times 759 \times 0.49\right)/2.0$$

$$\Delta k\text{Wh} = -3.7 \text{kWh}$$

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

$$\Delta k\text{W} = \left(\frac{(\text{WattsBase} - \text{WattsEE})}{1000}\right) \times \text{ISR} \times \text{WHFd} \times \text{CF}$$

Where:

- 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>1.11^{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 = 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 compared 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.

\[
\Delta \text{Therms} = \frac{(\text{WattsBase} - \text{WattsEE})}{1000} \times \text{ISR} \times \text{HF} \times 0.03412 / \eta_{\text{Heat}}
\]

Where:

- \( \text{HF} \) = 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</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 below\(^896\). 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>Residential and in-unit Multi</td>
<td>Lumens &lt;310 or &gt;2600 (non-EISA compliant)</td>
<td>$2.86</td>
<td>$2.86</td>
</tr>
<tr>
<td>Family</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.

\[
CF_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)}
\]

---

\[ \Delta kWh = \Delta kWh_\text{cooling} + \Delta kWh_\text{heating} \]

Where:

\[
\Delta kWh_\text{cooling} = \text{If central cooling, reduction in annual cooling requirement due to air sealing} \\
= \left(\frac{([((\text{CFM50}_{\text{existing}} - \text{CFM50}_{\text{new}})/N_\text{cool}}) * 60 * 24 * \text{CDD} * \text{DUA} * 0.018)}{(1000 * \eta_\text{Cool}}) \right) \times \text{LM} \\
\text{CFM50}_{\text{existing}} = \text{Infiltration at 50 Pascals as measured by blower door before air sealing.} \\
= \text{Actual} \\
\text{CFM50}_{\text{new}} = \text{Infiltration at 50 Pascals as measured by blower door after air sealing.} \\
= \text{Actual} \\
N_\text{cool} = \text{Conversion factor from leakage at 50 Pascal to leakage at natural conditions} \\
= \text{Dependent on location and number of stories:}^{902}

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>N_\text{cool} (by # of stories)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1 (Rockford)</td>
<td>39.5</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>38.9</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>41.2</td>
</tr>
<tr>
<td>4 (St Louis, MO)</td>
<td>40.4</td>
</tr>
<tr>
<td>5 (Paducah, KY)</td>
<td>43.6</td>
</tr>
</tbody>
</table>

899 Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

900 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)’.

901 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.

902 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”.
60 * 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

= Dependent on location\(^{903}\):

<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 \(^{904}\)

0.018 = Specific Heat Capacity of Air (Btu/ft\(^3\)*°F)

1000 = Converts Btu to kBtu

\(\eta_{\text{Cool}}\) = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual (where it is possible to measure or reasonably estimate). If unknown assume the following\(^{905}\):

<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\(^{906}\)

<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>

\(\Delta k\text{Wh}_{\text{heating}}\) = If electric heat (resistance or heat pump), reduction in annual electric heating due to

\(^{903}\) National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F.

\(^{904}\) 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.

\(^{905}\) 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.

\(^{906}\) Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”.

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Air sealing

\[
\text{air sealing} = (((\text{CFM50}_{\text{existing}} - \text{CFM50}_{\text{new}})/N_{\text{heat}}) \times 60 \times 24 \times \text{HDD} \times 0.018) / (\eta_{\text{Heat}} \times 3,412)
\]

\(N_{\text{heat}}\) = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

\(\text{HDD}\) = Heating Degree Days

\(\eta_{\text{Heat}}\) = Efficiency of heating system

\(3412\) = Converts Btu to kWh

---

**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”.

**National Climatic Data Center**, calculated from 1981-2010 climate normals with a base temp of 60°F.

**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:

\[
\Delta k\text{Wh}_{\text{heating}} = \Delta k\text{Wh}_{\text{cooling}} + \Delta k\text{Wh}_{\text{heating}} \\
= [(3,400 – 2,250) / 31.6] * 60 * 24 * 842 * 0.75 * 0.018 / (1000 * 10.5) * 3.2] + [(3,400 – 2,250) / 19.4] * 60 * 24 * 5113 * 0.018 / (1.92 * 3,412] \\
= 182 + 1199 \\
= 1,381 \text{kWh}
\]

\[
\Delta k\text{Wh}_{\text{heating}} = \text{If gas furnace heat, kWh savings for reduction in fan run time} \\
= \Delta \text{Therms} * F_e * 29.3 \\
F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption} \\
= 3.14\%^910 \\
29.3 = \text{kWh per therm}
\]

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.

\[
\Delta k\text{Wh}_{\text{heating}} = (\Delta k\text{Wh}_{\text{gasket}} * n_{\text{gasket}} + \Delta k\text{Wh}_{\text{sweep}} * n_{\text{sweep}} + \Delta k\text{Wh}_{\text{sealing}} * l_f_{\text{sealing}} + \Delta k\text{Wh}_{\text{WX}} * l_f_{\text{WX}}) \cdot ADJ_{\text{Rx Airsealing}}
\]

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>$\Delta k\text{Wh}_{\text{gasket}} / \text{gasket}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Resistance</td>
<td>Heat Pump</td>
</tr>
<tr>
<td>1 (Rockford)</td>
<td>10.5</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>10.2</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>8.8</td>
</tr>
</tbody>
</table>

^910 $F_e$ 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.xls” for reference.

### Air Sealing

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>$\Delta \text{kWh}_{\text{gasket}} / \text{gasket}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electric Resistance</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>7.0</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>7.2</td>
</tr>
</tbody>
</table>

- $n_{\text{gasket}}$ = Number of gaskets installed
- $\Delta \text{kWh}_{\text{sweep}}$ = Annual kWh savings from installation of door sweep

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>$\Delta \text{kWh}_{\text{sweep}} / \text{sweep}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electric Resistance</td>
</tr>
<tr>
<td>1 (Rockford)</td>
<td>202.4</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>195.3</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>169.3</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>134.9</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>137.9</td>
</tr>
</tbody>
</table>

- $n_{\text{sweep}}$ = Number of sweeps installed
- $\Delta \text{kWh}_{\text{sealing}}$ = Annual kWh savings from foot of caulking, sealing, or polyethylene tape

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>$\Delta \text{kWh}_{\text{sealing}} / \text{ft}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electric Resistance</td>
</tr>
<tr>
<td>1 (Rockford)</td>
<td>11.6</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>11.2</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>9.7</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>7.7</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>7.9</td>
</tr>
</tbody>
</table>

- $l_{\text{sealing}}$ = linear feet of caulking, sealing, or polyethylene tape
- $\Delta \text{kWh}_{\text{WX}}$ = Annual kWh savings from window weatherstripping or door weatherstripping

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>$\Delta \text{kWh}_{\text{WX}} / \text{ft}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electric Resistance</td>
</tr>
<tr>
<td>1 (Rockford)</td>
<td>13.5</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>13.0</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>11.3</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>9.0</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>9.2</td>
</tr>
</tbody>
</table>

- $l_{\text{WX}}$ = Linear feet of window weatherstripping or door weatherstripping
- $\text{ADJ}_{\text{Airsealing}}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings. 
  - $\text{ADJ}_{\text{Airsealing}} = 80\%$

---

912 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**

\[
\Delta kW = \left( \frac{\Delta kWH\text{\_cooling}}{FLH\text{\_cooling}} \right) \times CF
\]

Where:

- \( FLH\text{\_cooling} \) = Full load hours of air conditioning
- \( FLH\text{\_cooling} \) = 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>

- \( CF\text{\_SSP} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour) = 68\(^{914}\%\)
- \( CF\text{\_SSP} \) = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) = 72\(^{915}\%\)
- \( CF\text{\_PJM} \) = 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:

\[
\Delta kW\text{\_SSP} = \frac{182}{570} \times 0.68 = 0.22 kW
\]

\[
\Delta kW\text{\_PJM} = \frac{182}{570} \times 0.466 = 0.15 kW
\]

**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.
\[
\Delta \text{Therms} = \frac{((\text{CFM50}_{\text{existing}} - \text{CFM50}_{\text{new}})/N_{\text{heat}}) \times 60 \times 24 \times \text{HDD} \times 0.018}{(\eta_{\text{Heat}} \times 100,000)}
\]

Where:

- \( N_{\text{heat}} \) = Conversion factor from leakage at 50 Pascal to leakage at natural conditions
- \( \eta_{\text{Heat}} \) = Efficiency of heating system
- \( \text{HDD} \) = Heating Degree Days

### Climate Zone (City based upon)

<table>
<thead>
<tr>
<th>N_heat (by # of stories)</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>23.8</td>
<td>21.1</td>
<td>19.3</td>
<td>17.1</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>23.9</td>
<td>21.1</td>
<td>19.4</td>
<td>17.2</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>24.2</td>
<td>21.5</td>
<td>19.7</td>
<td>17.4</td>
</tr>
<tr>
<td>4 (St Louis, MO)</td>
<td>25.4</td>
<td>22.5</td>
<td>20.7</td>
<td>18.3</td>
</tr>
<tr>
<td>5 (Paducah, KY)</td>
<td>27.8</td>
<td>24.6</td>
<td>22.6</td>
<td>20.0</td>
</tr>
</tbody>
</table>

### HDD

- \( \text{HDD} \) = Heating Degree Days
- Based 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>

### 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:

\[
\Delta \text{Therms} = \frac{((3,400 - 2,250)/19.4) \times 60 \times 24 \times 5113 \times 0.018}{(0.72 \times 100,000)}
\]

\[= 109.1 \text{ therms}\]

---

\(^{917}\) 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”.

\(^{918}\) 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..

\(^{919}\) 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.

\[
\Delta \text{therms} = (\Delta \text{therms}_{\text{gasket}} \times n_{\text{gasket}} + \Delta \text{therms}_{\text{sweep}} \times n_{\text{sweep}} + \Delta \text{therms}_{\text{sealing}} \times l_{\text{sealing}} + \Delta \text{therms}_{\text{WX}} \times l_{\text{WX}}) \times ADJ_{\text{RxAirsealing}}
\]

Where:

\(\Delta \text{therms}_{\text{gasket}}\) = Annual therm savings from installation of air sealing gasket on an electric outlet

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>(\Delta \text{therms}_{\text{gasket}} / \text{gasket})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>0.49</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>0.47</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>0.41</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>0.33</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>0.33</td>
</tr>
</tbody>
</table>

\(n_{\text{gasket}}\) = Number of gaskets installed

\(\Delta \text{therms}_{\text{sweep}}\) = Annual therm savings from installation of door sweep

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>(\Delta \text{therms}_{\text{sweep}} / \text{sweep})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>9.46</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>9.13</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>7.92</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>6.31</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>6.45</td>
</tr>
</tbody>
</table>

\(n_{\text{sweep}}\) = Number of sweeps installed

\(\Delta \text{therms}_{\text{sealing}}\) = Annual therm savings from foot of caulking, sealing, or polyethylene tape

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>(\Delta \text{therms}_{\text{sealing}} / \text{ft})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>0.54</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>0.52</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>0.45</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>0.36</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>0.37</td>
</tr>
</tbody>
</table>

\(l_{\text{sealing}}\) = linear feet of caulking, sealing, or polyethylene tape

\(\Delta \text{therms}_{\text{WX}}\) = Annual therm savings from window weatherstripping or door weatherstripping

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>(\Delta \text{therms}_{\text{WX}} / \text{ft})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>0.63</td>
</tr>
</tbody>
</table>

### 5.6.1 Air Sealing

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>$\Delta \text{therms}_x / \text{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>

$l_{Wx}$ = Linear feet of window weatherstripping or door weatherstripping

$ADJ_{RxAirsealing}$ = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings\(^{922}\).

$= 80\%$

**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.

\[
\text{CF}_{\text{SSP}} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)}
\]

\[
\text{CF}_{\text{SSP}} = 68\% \quad ^{924}\]


\(^{924}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.
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.

\[ \Delta k\text{Wh} = (\Delta k\text{Wh\_cooling} + \Delta k\text{Wh\_heating}) \]

Where:

- \( \Delta k\text{Wh\_cooling} \) = If central cooling, reduction in annual cooling requirement due to insulation
  \[ = \frac{((1/R\_old\_AG - 1/(R\_added+R\_old\_AG)) \times L\_basement\_wall\_total \times H\_basement\_wall\_AG \times (1 - Framing\_factor)) \times 24 \times CDD \times DUA}{(1000 \times \eta\text{Cool})} \times ADJ_{\text{BasementCool}} \]
- \( R\_added \) = R-value of additional spray foam, rigid foam, or cavity insulation.
- \( R\_old\_AG \) = R-value value of foundation wall above grade.
  = Actual, if unknown assume 1.0
- \( L\_basement\_wall\_total \) = Length of basement wall around the entire insulated perimeter (ft)
- \( H\_basement\_wall\_AG \) = Height of insulated basement wall above grade (ft)
- Framing\_factor = Adjustment to account for area of framing when cavity insulation is used
  = 0% if Spray Foam or External Rigid Foam
  = 25% if studs and cavity insulation
- 24 = Converts hours to days
- CDD = Cooling Degree Days
  = Dependent on location and whether basement is conditioned.

---

925 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 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 ASHRAE, 2001, “Characterization of Framing Factors for New Low-Rise Residential Building Envelopes (904-RP),” Table 7.1
929 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><strong>Weighted Average</strong>&lt;sup&gt;931&lt;/sup&gt;</td>
<td><strong>947</strong></td>
<td><strong>325</strong></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

\[
\Delta kWh_{heating} = \left(\frac{((1/R_{old\_BG} - 1/(R_{added}+R_{old\_BG})) \times L_{basement\_wall\_total} \times H_{basement\_wall\_AG} \times (1-\text{Framing\_factor})) + ((1/R_{old\_AG} - 1/(R_{added}+R_{old\_AG})) \times L_{basement\_wall\_total} \times (H_{basement\_wall\_total} - H_{basement\_wall\_AG}) \times (1-\text{Framing\_factor}))]}{(3,412 \times \eta\_Heat) \times ADJ_{BasementHeat}} \right) \\
\text{Where} \\
R_{old\_BG} = \text{R-value value of foundation wall below grade (including thermal resistance of}
\]

<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) \[^{935}\]

\[ = \text{dependent on depth of foundation (H_{basement\_wall\_total} - H_{basement\_wall\_AG})} \]

\[ = \text{Actual R-value of wall plus average earth R-value by depth in table below} \]

<table>
<thead>
<tr>
<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 (°F-ft²-h/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>
</tr>
<tr>
<td>Average Earth R-value (°F-ft²-h/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>
</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>
</tr>
</tbody>
</table>

\[ H_{basement\_wall\_total} = \text{Total height of basement wall (ft)} \]

\[ \text{HDD} = \text{Heating Degree Days} \]

\[ = \text{dependent on location and whether basement is conditioned}^{936} \]

<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[^{937}]</td>
<td>4,860</td>
<td>2,895</td>
</tr>
</tbody>
</table>

\[ \eta_{Heat} = \text{Efficiency of heating system} \]

\[ = \text{Actual. If not available refer to default table below}^{938} \]

<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \eta_{Heat} (\text{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>

\[^{935}\] Adapted from Table 1, page 24.4, of the 1977 ASHRAE Fundamentals Handbook

\[^{936}\] 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.

\[^{937}\] Weighted based on number of occupied residential housing units in each zone.

\[^{938}\] 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.
<table>
<thead>
<tr>
<th>System Type</th>
<th>Age of Equipment</th>
<th>HSPF Estimate</th>
<th>( \eta_{\text{Heat}} ) (Effective COP Estimate) ( \frac{(\text{HSPF}/3.413) \times 0.85}{1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2015 on</td>
<td>8.2</td>
<td>2.04</td>
</tr>
</tbody>
</table>

\[ \text{ADJ}_{\text{BasementHeat}} = \text{Adjustment for basement wall insulation to account for prescriptive engineering algorithms overclaiming savings}^{939}. \]

\[ = 60\% \]

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:

\[
\Delta \text{kWh} = (\Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}})
\]

\[
= [(((1/2.25 - 1/(13 + 2.25)) \times (20+25+20+25) \times 3 \times (1 - 0)) \times 24 \times 281 \times 0.75)/(1000 \times 10.5)) \times 0.8] + [(((1/2.25 - 1/(13 + 2.25)) \times (20+25+20+25) \times 3 \times (1-0)) + ((1/(2.25 + 6.42) - 1/(13 + 2.25 + 6.42)) \times (20+25+20+25) \times 4 \times (1-0))) \times 24 \times 3079]/(3412 \times 1.92) \times 0.6]
\]

\[
= (39.4 + 860.9)
\]

\[
= 900.3 \text{ kWh}
\]

\[
\Delta \text{kWh}_{\text{heating}} = \text{If gas furnace heat, kWh savings for reduction in fan run time}
\]

\[
= \Delta \text{Therms} \times F_e \times 29.3
\]

\[
F_e = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption}
\]

\[
= 3.14\%^{940}
\]

\[
29.3 = \text{kWh per therm}
\]

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):

\[
= 78.3 \times 0.0314 \times 29.3
\]

\[
= 72.0 \text{ kWh}
\]

**SUMMER COINCIDENT PEAK DEMAND**

\[
\Delta \text{kW} = (\Delta \text{kWh}_{\text{cooling}} / \text{FLH}_{\text{cooling}}) \times CF
\]

Where:

\[
\text{FLH}_{\text{cooling}} = \text{Full load hours of air conditioning}
\]

\(^{939}\) 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 MBtu/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.
Basement Sidewall Insulation

Climate Zone (City based upon) | Single Family | Multifamily
--- | --- | ---
1 (Rockford) | 512 | 467
2 (Chicago) | 570 | 506
3 (Springfield) | 730 | 663
4 (Belleville) | 1,035 | 940
5 (Marion) | 903 | 820
Weighted Average

- \( CF_{SSP} = \) Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
- \( CF_{SSP} = 68\% \)
- \( CF_{SSP} = \) Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)
- \( CF_{SSP} = 72\% \)
- \( CF_{PJM} = \) PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)
- \( CF_{PJM} = 46.6\% \)

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:

\[
\Delta kW_{SSP} = \frac{39.4}{570} \times 0.68 = 0.047 \text{ kW}
\]

\[
\Delta kW_{PJM} = \frac{39.4}{570} \times 0.466 = 0.032 \text{ kW}
\]

**NATURAL GAS SAVINGS**

If Natural Gas heating:

\[
\Delta \text{Therms} = \left( \frac{1}{R_{old\_AG}} - \frac{1}{R_{added} + R_{old\_AG}} \right) \times L_{basement\_wall\_total} \times H_{basement\_wall\_AG} \times (1 - \text{Framing\_factor}) + \left( \frac{1}{R_{old\_BG}} - \frac{1}{R_{added} + R_{old\_BG}} \right) \times L_{basement\_wall\_total} \times (H_{basement\_wall\_total} - H_{basement\_wall\_AG}) \times (1 - \text{Framing\_factor}) \times 24 \times \text{HDD} \times \frac{\eta_{Heat} \times 100,067}{100} \times ADJ_{basement\_heat}
\]

\[\eta_{Heat} = \text{Efficiency of heating system}\]

**Notes:**

- \(941\) Full load hours for Chicago, Moline and Rockford are provided in “Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), 2010, Navigant Consulting”, [http://ilsagfiles.org/SAG_files/Evaluation_Documents/ComEd/ComEd%20EPY2%20Evaluation%20Reports/ComEd_Central_AC_Efficiency_Services_PY2_Evaluation_Report_Final.pdf](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:

\[
\begin{align*}
= & \left( \frac{1}{2.25} - \frac{1}{1(13 + 2.25)} \right) * \left( \frac{20+25+20+25}{3} * (1-0) \right) + \left( \frac{1}{8.67} - \frac{1}{1(13 + 8.67)} \right) * \left( \frac{20+25+20+25}{4} * (1-0) \right) * 24 * 3079 \right) / (0.72 * 100,067) * 0.60 \\
= & 78.3 \text{ therms}
\end{align*}
\]

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.

---

\[ C_{SSP} = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \]
\[ = 68\%^{948} \]
\[ C_{SSP} = \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \]
\[ = 72\%^{949} \]
\[ C_{PJM} = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)} \]
\[ = 46.6\%^{950} \]

**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.

\[
\Delta \text{kWh} = (\Delta \text{kWh}_{\text{cooling}} + \Delta \text{kWh}_{\text{heating}})
\]

Where:

\[
\Delta \text{kWh}_{\text{cooling}} = \text{If central cooling, reduction in annual cooling requirement due to insulation}
\]

\[
= (((1/R_{old} - 1/(R_{added} + R_{old})) * \text{Area} * (1 - \text{Framing factor}) * 24 * \text{CDD} * \text{DUA}) / (1000 * \eta_{\text{Cool}})) * \text{ADJ}_{\text{FloorCool}}
\]

\[ R_{old} = \text{R-value value of floor before insulation, assuming 3/4” plywood subfloor and carpet with pad} \]
\[ = \text{Actual. If unknown assume 3.96}^{951} \]

\[ R_{added} = \text{R-value of additional spray foam, rigid foam, or cavity insulation.} \]

\[ \text{Area} = \text{Total floor area to be insulated} \]

\[ \text{Framing factor} = \text{Adjustment to account for area of framing} \]
\[ = 12\%^{952} \]

\[ 24 = \text{Converts hours to days} \]

\[ \text{CDD} = \text{Cooling Degree Days} \]

---

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
--- | ---
1 (Rockford) | 263
2 (Chicago) | 281
3 (Springfield) | 436
4 (Belleville) | 538
5 (Marion) | 570
Weighted Average | 325

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

\[= 0.75 \quad 955\]

1000 = Converts Btu to kBtu

\[\eta_{\text{Cool}} = \text{Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)}\]

\[= \text{Actual (where it is possible to measure or reasonably estimate). If unknown assume the following:}^{956}\]

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>(\eta_{\text{Cool}}) 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>

\[\text{ADJ}_{\text{FloorCool}} = \text{Adjustment for cooling savings from floor to account for prescriptive engineering algorithms overclaiming savings}^{957}.

\[= 80\%\]

\[\Delta \text{kWh}_\text{heating} = \text{If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation}

\[= (((1/R_{\text{old}} - 1/(R_{\text{added}} + R_{\text{old}})) \times \text{Area} \times (1-\text{Framing_factor}) \times 24 \times \text{HDD})/ (3,412 \times \eta_{\text{Heat}})) \times \text{ADJ}_{\text{FloorHeat}}\]

\[\text{HDD} = \text{Heating Degree Days:}^{958}\]

---

953 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.

954 Weighted based on number of occupied residential housing units in each zone.

955 Energy Center of Wisconsin, May 2008 metering study; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research”, p31.

956 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.

957 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%.

958 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.
### Floor Insulation Above Crawlspace

<table>
<thead>
<tr>
<th>Climate Zone (City based upon)</th>
<th>Unconditioned HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (Rockford)</td>
<td>3,322</td>
</tr>
<tr>
<td>2 (Chicago)</td>
<td>3,079</td>
</tr>
<tr>
<td>3 (Springfield)</td>
<td>2,550</td>
</tr>
<tr>
<td>4 (Belleville)</td>
<td>1,789</td>
</tr>
<tr>
<td>5 (Marion)</td>
<td>1,796</td>
</tr>
<tr>
<td>Weighted Average(^{959})</td>
<td>2,895</td>
</tr>
</tbody>
</table>

\( \eta_{\text{Heat}} \) = Efficiency of heating system

\( \eta_{\text{Heat}} \) = Actual. If not available refer to default table below:\(^{960}\)

<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>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>

\( ADJ_{\text{Floor Heat}} \) = Adjustment for floor insulation to account for prescriptive engineering algorithms overclaiming savings\(^{961}\).

\( ADJ_{\text{Floor Heat}} \) = 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:

\[
\Delta k_{\text{Watt}} = (\Delta k_{\text{Watt, cooling}} + \Delta k_{\text{Watt, heating}})
\]

\[
\Delta k_{\text{Watt}} = (\frac{(1/3.96 - 1/(30+3.96)}{20*25}*(1-0.12)* 24 * 281*0.75)/(1000*10.5)) * 0.8 + ((1/3.96 - 1/(30+3.96)}{20*25}*(1-0.15) * 24 * 3079)/(3412*1.92)) * 0.6)
\]

\[
= (37.8 + 641.7)
\]

\[
= 679.5 \text{ kWh}
\]

\[
\Delta k_{\text{Watt, heating}} = \text{If gas furnace heat, kWh savings for reduction in fan run time}
\]

\[
= \Delta \text{Therms} \times F_{e} \times 29.3
\]

\[
F_{e} = \text{Furnace Fan energy consumption as a percentage of annual fuel consumption}
\]

---

\(^{959}\) 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%\(^{962}\)
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):
\[\Delta kWh = 60.4 \times 0.0314 \times 29.3\]
\[= 55.6 \text{ kWh}\]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[\Delta kW = (\Delta kWh\text{\_cooling} / FLH\text{\_cooling}) \times CF\]

Where:

- **FLH\text{\_cooling} =** Full load hours of air conditioning
- Depends on location:\(^{963}\)

<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(^{964})</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

- **CF\text{SSP} =** Summer System Peak Coincidence Factor for Central A/C (during system peak hour)
  = 68%\(^{965}\)
- **CF\text{SSP} =** Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)
  = 72%\(^{966}\)
- **CF\text{PJM} =** PJM Summer Peak Coincidence Factor for Central A/C (average during peak period)

\(^{962}\) \(F_e\) 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 (\(E_f\) in MMBtu/yr) and \(E_{ae}\) (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.

\(^{963}\) 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.

\(^{964}\) Weighted based on number of occupied residential housing units in each zone.

\(^{965}\) Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory.

\(^{966}\) 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:

\[
\Delta \text{Therms} = \frac{(1/R_{\text{old}} - 1/(R_{\text{added}}+R_{\text{old}})) \times \text{Area} \times (1-\text{Framing\_factor}) \times 24 \times \text{HDD}}{(100,000 \times \eta_{\text{Heat}}) \times \text{ADJ}_{\text{FloorHeat}}}
\]

Where

\[
\eta_{\text{Heat}} = \text{Efficiency of heating system} = \text{Equipment efficiency} \times \text{distribution efficiency} = \text{Actual. If unknown assume 72%}\]

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

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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.

\[
\begin{align*}
CF_{SSP} & = \text{Summer System Peak Coincidence Factor for Central A/C (during utility peak hour)} \\
& = 68\%^{970} \\
CF_{SSP} & = \text{Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)} \\
& = 72\%^{971} \\
CF_{PJM} & = \text{PJM Summer Peak Coincidence Factor for Central A/C (average during PJM peak period)}
\end{align*}
\]


\(^970\) 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)’. 

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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
- $\Delta k\text{Wh}_{\text{heating}}$ = (1/R_old - 1/R_wall) * A_wall * (1 - Framing_factor_wall) + (1/R_old - 1/R_attic) * A_attic * (1 - Framing_factor_attic) * 24 * CDD * DUA / (1000 * ηCool) * ADJ WallAtticCool
- R_wall = R-value of new wall assembly (including all layers between inside air and outside air).
- R_attic = R-value of new attic assembly (including all layers between inside air and outside air).
- R_old = R-value value of existing assemble and any existing insulation.
  (Minimum of R-5 for uninsulated assemblies)
- A_wall = Net area of insulated wall (ft$^2$)
- A_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  
--- | ---  
3 (Springfield) | 1,108  
4 (Belleville) | 1,570  
5 (Marion) | 1,370  
Weighted Average\(^77\) | 947

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).  
\(= 0.75 \) \(^78\)

1000 = Converts Btu to kBtu

\(\eta_{\text{Cool}}\) = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

\(= \text{Actual} (\text{where it is possible to measure or reasonably estimate). If unknown assume the following:}\) \(^79\)

<table>
<thead>
<tr>
<th>Age of Equipment</th>
<th>(\eta_{\text{Cool}}) 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>

\(\text{ADJ}_{\text{WallAtticCool}}\) = Adjustment for cooling savings from basement wall insulation to account for prescriptive engineering algorithms overclaiming savings. \(^80\)

\(= 80\%\)

\(kWh_{\text{heating}}\) = If electric heat (resistance or heat pump), reduction in annual electric heating due to insulation

\[=((1/R_{\text{old}} - 1/R_{\text{wall}}) * A_{\text{wall}} * (1 - \text{Framing factor}_{\text{wall}})) + (1/R_{\text{old}} - 1/R_{\text{attic}}) * A_{\text{attic}} * (1 - \text{Framing factor}_{\text{attic}}) * 24 * \text{HDD} / (\eta_{\text{Heat}} * 3412)) * \text{ADJ}_{\text{WallAtticHeat}}\]

\(\text{HDD}\) = Heating Degree Days

\(= \text{Dependent on location.}\) \(^81\)

---

\(^{77}\) Weighted based on number of occupied residential housing units in each zone.  
\(^{78}\) 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.  
\(^{79}\) 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.  
\(^{80}\) 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%.  
\(^{81}\) 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 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.
Climate Zone | HDD 60
---|---
1 (Rockford) | 5,352
2 (Chicago) | 5,113
3 (Springfield) | 4,379
4 (Belleville) | 3,378
5 (Marion) | 3,438
Weighted Average | 4,860

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>

3412 = Converts Btu to kWh

ADJWallAtticHeat = Adjustment for wall and attic insulation to account for prescriptive engineering algorithms overclaiming savings.

= 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, 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump:

\[
\Delta kW_h = (\Delta kW_h_{cooling} + \Delta kW_h_{heating})
\]

\[
= \left(\frac{\left(\frac{1}{5} - \frac{1}{11}\right) \times 990 \times (1-0.25)}{1000} + \left(\frac{1}{5} - \frac{1}{38}\right) \times 700 \times (1-0.07)\right) \times 842 \times 0.75 \times 24 + \left(\frac{\left(\frac{1}{5} - \frac{1}{11}\right) \times 990 \times (1-0.25)}{1000} + \left(\frac{1}{5} - \frac{1}{38}\right) \times 700 \times (1-0.07)\right) \times 5113 \times 24 / (1.92 \times 3412) - 0.6
\]

\[
= 224 + 2181
\]

\[
= 2405\ kWh
\]

\[
\Delta kW_h_{heating} = \text{If gas furnace heat, kWh savings for reduction in fan run time}
\]

\[
= \Delta T_{\text{He}} \times F_e \times 29.3
\]

F_e = 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 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% (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**

\[
\Delta kW = (\Delta \text{kWh}_{\text{cooling}} / FLH_{\text{cooling}}) \times CF
\]

**Where:**

- \( FLH_{\text{cooling}} \) = Full load hours of air conditioning
- \( CF_{\text{SSP}} \) = Summer System Peak Coincidence Factor for Central A/C (during system peak hour) 
  \( = 68\%\)
- \( CF_{\text{SSP}} \) = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour) 
  \( = 72\%\)
- \( CF_{\text{PJM}} \) = PJM Summer Peak Coincidence Factor for Central A/C (average during peak period) 
  \( = 46.6\%\)

<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(^{987})</td>
<td>629</td>
<td>564</td>
</tr>
</tbody>
</table>

\(^{985}\) Fe 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% Fe. 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.
NATURAL GAS SAVINGS

If Natural Gas heating:

\[
\Delta \text{Therm} = \frac{(((1/R_{\text{old}} - 1/R_{\text{wall}}) \times A_{\text{wall}} \times (1 - \text{Framing factor}_{\text{wall}})) + ((1/R_{\text{old}} - 1/R_{\text{attic}}) \times A_{\text{attic}} \times (1 - \text{Framing factor}_{\text{attic}})) \times 24 \times \text{HDD}}{(\eta_{\text{Heat}} \times 100,067 \text{ Btu/therm}) \times \text{ADJ}_{\text{WallAtticHeat}}}
\]

Where:

\[
\text{HDD} = \text{Heating Degree Days}
\]

\[
\text{Dependent on location:}^{991}
\]

<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>
<tr>
<td>Weighted Average</td>
<td>4,860</td>
</tr>
</tbody>
</table>

\[
\eta_{\text{Heat}} = \text{Efficiency of heating system}
\]

\[
= \text{Equipment efficiency} \times \text{distribution efficiency}
\]

\[
= \text{Actual}^{993} \text{ if unknown assume 72\%}^{994}
\]

Other factors as defined above

---

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%:

$$\Delta \text{Therms} = \frac{(((1/5 - 1/11) \times 990 \times (1 - 0.25)) + ((1/5 - 1/38) \times 700 \times (1 - 0.07))) \times 24 \times 5113}{(0.66 \times 100,067) \times 0.60}$$

$$= 216.4 \text{ therms}$$

**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.

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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

\[ \Delta k\text{Wh two speed} = \frac{\left(\frac{\text{Hrs/Day}_{\text{base}} \times \text{GPM}_{\text{base}} \times 60}{\text{EF}_{\text{base}}} - \left(\frac{\text{Hrs/Day}_{2\text{spH}} \times \text{GPM}_{2\text{spH}} \times 60}{\text{EF}_{2\text{spH}}} + \left(\frac{\text{Hrs/Day}_{2\text{spL}} \times \text{GPM}_{2\text{spL}} \times 60}{\text{EF}_{2\text{spL}}}ight)\right)\right)}{1000 \times \text{Days}} \]

\[ \Delta k\text{Wh variable speed} = \frac{\left(\frac{\text{Hrs/Day}_{\text{base}} \times \text{GPM}_{\text{base}} \times 60}{\text{EF}_{\text{base}}} - \left(\frac{\text{Hrs/Day}_{\text{vsH}} \times \text{GPM}_{\text{vsH}} \times 60}{\text{EF}_{\text{vsH}}} + \left(\frac{\text{Hrs/Day}_{\text{vsL}} \times \text{GPM}_{\text{vsL}} \times 60}{\text{EF}_{\text{vsL}}}ight)\right)\right)}{1000 \times \text{Days}} \]

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
- \( \text{Hrs/Day}_{2\text{spH}} \) = run hours of two speed pump at high speed = 2
- \( \text{GPM}_{2\text{spH}} \) = flow of two speed pump at high speed (gal/min) = 56
- \( \text{EF}_{2\text{spH}} \) = Energy Factor of two speed pump at high speed (gal/Wh) = 2.4
- \( \text{Hrs/Day}_{2\text{spL}} \) = run hours of two speed pump at low speed = 15.7
- \( \text{GPM}_{2\text{spL}} \) = flow of two speed pump at low speed (gal/min) = 31
- \( \text{EF}_{2\text{spL}} \) = Energy Factor of two speed pump at high 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.
\[ Hrs/Day_{vsl} = \text{run hours of variable speed pump at low speed} = 3.8 \]
\[ GPM_{vsl} = \text{flow of variable speed pump at low speed (gal/min)} = 16 \]
\[ EF_{vsl} = \text{Energy Factor of variable speed pump at high speed (gal/Wh)} = 30.6 \]
\[ Days = \text{Number of days per year that the swimming pool is operational} = 125^{1000} \]
\[ \Delta \text{kWh two speed} = (((11.4 \times 64.4 \times 60)/2.1) - (((2 \times 56 \times 60)/2.4 + ((15.7 \times 31 \times 60)/5.4))))/1000 \times 125 = 1,596.0 \text{ kWh} \]
\[ \Delta \text{kWh variable speed} = (((11.4 \times 64.4 \times 60)/2.1) - (((2 \times 50 \times 60)/3.8 + ((16 \times 30.6 \times 60)/7.3))))/1000 \times 125 = 1,921.6 \text{ kWh} \]

**SUMMER COINCIDENT PEAK DEMAND SAVINGS**

\[ \Delta \text{kW two speed} = ((\text{kWh/day}_{base}/(\text{Hrs/day}_{base}) - (\text{kWh/day}_{2sp}/(\text{Hr/day}_{2sp}))) \times \text{CF} \]
\[ \Delta \text{kW variable speed} = ((\text{kWh/day}_{base}/(\text{Hrs/day}_{base}) - (\text{kWh/day}_{var}/(\text{Hr/day}_{var}))) \times \text{CF} \]

Where:

\[ \text{kWh/day}_{base} = \text{daily energy consumption of baseline pump, as defined above} = 20.98 \]
\[ \text{Hrs/day}_{base} = \text{daily run hours of single speed pump} = 11.4 \]
\[ \text{kWh/day}_{2sp} = \text{daily energy consumption of two speed pump, as defined above} = 8.21 \]
\[ \text{Hr/day}_{2sp} = \text{run hours of two speed pump} = 17.7 \]
\[ \text{kWh/day}_{var} = \text{daily energy consumption of variable speed pump, as defined above} = 5.6 \]
\[ \text{Hr/day}_{var} = \text{run hours of variable speed pump} = 18 \]

---

1000 Assumess 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 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.
CF = Summer Peak Coincidence Factor for measure
= 0.831

\[ \Delta kW \text{ two speed} = (\frac{20.98}{11.4} - \frac{8.21}{17.7}) \times 0.831 \]
\[ = 1.144 \text{ kW} \]

\[ \Delta kW \text{ variable speed} = (\frac{20.98}{11.4} - \frac{5.60}{18}) \times 0.831 \]
\[ = 1.271 \text{ kW} \]

**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

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.