Memorandum

To: Technical Advisory Committee

**FROM:** KALEE WHITEHOUSE, PROJECT MANAGER, and SAM DENT, TECHNICAL LEAD - VEIC

subject: v9.0 Errata Measures effective 01/01/2021

date: 09/10/2021

**Cc:** CELIA JOHNSON, SAG

This memo documents errata changes to Version 9.0 of the Illinois Technical Reference Manual (TRM) that the Technical Advisory Committee (TAC) recommends be made effective 01/01/2021.

VEIC has provided a summary table below showing the errata measures and a brief summary of what was changed, followed by the v9.0 measures themselves.

TRM Policy Document, Section 3.2.1, states that,

“TAC participants should notify the TAC when a TRM mistake or omission is found. If a significant mistake or omission is found in the TRM that results in an unreasonable savings estimate, the Program Administrators, Evaluators, TRM Administrator, and TAC will strive to reach consensus on a solution that will result in a reasonable savings estimate. For example, an unreasonable savings estimate may result from an error or omission in the TRM.

“In these limited cases where consensus is reached, the TRM Administrator shall inform the Evaluators to use corrected TRM algorithms and inputs to calculate energy and capacity savings, in addition to using the Commission-approved TRM algorithms and inputs to calculate savings. If the corrected TRM algorithms and inputs are stipulated for acceptance by all the parties in the Program Administrator’s savings docket, then the corrected TRM savings verification values may be used for the purpose of measuring savings toward compliance with the Program Administrator’s energy savings goals. Errors and omissions found in the TRM will be officially corrected through the annual TRM Update proceeding and will be identified as ‘Errata’.”

It is our belief and understanding that the following measures have been determined to be consensus errata by the Program Administrators, Evaluators, and the entire TAC. The term ‘errata’ is used to describe these measures, and in accordance with the TRM Policy Document, the Evaluators may use this version of the measures during evaluation of the current program year (in addition to the measures currently in Version 9.0 of the TRM).

**Summary of Errata Measures**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Section** | **Measure Name** | **Measure Code** | **Brief Summary of Change** | **TAC Reviewed and Approved As of** |
| 4.3.1 | Water Heater | CI-HWE-STWH-V07-210101 | Fix error in large (>12kW) electric unit standby loss calculation. Example calculations updated. | 07/12/2021 |
| 4.4 | HVAC End Use | N/A | Fix of existing building Heating and Cooling EFLH for ‘Office - High Rise - CAV econ’. | 07/12/2021 |
| 4.4.16 | Steam Trap Replacement or Repair | CI-HVC-STRE-V08-210101 | Fix error in Sa calculation for low pressure steam systems. The variable D should be squared.  | 11/3/2020 |
| 4.4.30 | Notched V Belts for HVAC Systems | CI-HVC-NVBE-V06-210101 | The HOU for High School was updated after recalculation using OpenStudio. This change was added in the first table for calculating EUL, but not in the second table for HOU.Also, measure did not have a CF applied to calculate summer coincident peak demand savings. This has been added. | 11/3/202007/12/2021 |
| 5.2.1 | Advanced Power Strips – Tier 1 | RS-CEL-SSTR-V07-210101 | Fix typo of 5-plug, Time of Sale ΔkW calculation result. | 11/3/2020 |
| 5.3.16 | Advanced Thermostats | RS-HVC-ADTH-V06-210101 | The heating % savings are reduced slightly to apply a 90% ISR to the additional Thermostat Optimization savings (the base heating % savings already incorporate inherent in service rate impacts).The ISR derived during the cooling savings analysis should therefore not be applied to the heating savings, so the ISR is now separated for heating (100%) and cooling (90%) calculations. | 11/3/2020 |
| 5.5.8 | LED Screw Based Omnidirectional Bulbs | RS-LTG-LEDA-V11-210101 | The mid-life adjustment percentage for IQ populations was incorrectly based on ComEd only lumen range frequency data, rather than ComEd and Ameren combined. When using combined, the value increases. | 07/12/2021 |
| 5.6.1 | Air Sealing | RS-SHL-AIRS-V10-210101 | Removal of IENetCorrection multiplier from ΔkWh\_heatingGas algorithm since this has already been applied in the ΔTherms algorithm. | 07/12/2021 |
| 5.6.5 | Ceiling/Attic Insulation | RS-SHL-AINS-V04-210101 | Removal of IENetCorrection multiplier from ΔkWh\_heatingGas algorithm since this has already been applied in the ΔTherms algorithm. | 07/12/2021 |

###

### Water Heater

###### Description

This measure is for upgrading from minimum code to a high efficiency water heater. Storage water heaters are used to supply hot water for a variety of commercial building types. Storage capacities vary greatly depending on the application. Large consumers of hot water include (but not limited to) industries, hotels/motels and restaurants.

Tankless water heaters function similar to standard hot water heaters except they do not have a storage tank. When there is a call for hot water, the water is heated instantaneously as it passes through the heating element and then proceeds to the user or appliance calling for hot water. Tankless water heaters achieve savings by eliminating the standby losses that occur in stand-alone or tank-type water heaters and by being more efficient than the baseline storage hot water heater.

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

###### Definition of Efficient Equipment

The minimum specifications of the high efficiency equipment should be defined by the programs.

###### Definition of Baseline Equipment

Time of Sale: The baseline condition is assumed to be a new standard water heater of same type as the existing unit being replaced, meeting the Federal Standard for ≤75,000 Btuh units and IECC 2018 for all others. If existing type is unknown, assume same water heater type as the efficient unit.

New Construction: The baseline condition is a new standard water heater of the same type as the efficient, meeting the IECC code level in place at the time the building permit was issued. Note IECC 2018 became effective July 1, 2019 and is the baseline for all New Construction permits from that date.

Note the same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units. Definitions of draw pattern are provided below.

| **Equipment Type** | **Sub Category** | **Draw Pattern**  | **Federal Standard – Uniform Energy Factor[[1]](#footnote-1)** |
| --- | --- | --- | --- |
| ResidentialGas Storage Water Heaters ≤75,000 Btu/h | ≤55 gallon tanks | Very small | UEF = 0.3456 – (0.0020 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.5982 – (0.0019 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.6483 – (0.0017 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.6920 – (0.0013 \* Rated Storage Volume in Gallons) |
| >55 gallon and ≤100 gallon tanks | Very small | UEF = 0.6470 – (0.0006 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.7689 – (0.0005 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.7897 – (0.0004 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.8072 – (0.0003 \* Rated Storage Volume in Gallons) |
| Residential-duty CommercialHigh Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h | ≤120 gallon tanks  | Very small | UEF = 0.2674 – (0.0009 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.5362 – (0.0012 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.6002 – (0.0011 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.6597 – (0.0009 \* Rated Storage Volume in Gallons) |
| CommercialGas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h | >120 gallon tanks | All | 80% Ethermal, Standby Losses = (Q /800 + 110√Rated Storage Volume in Gallons) |
| CommercialGas Storage Water Heaters >155,000 Btu/h |  |
| Residential Gas Instantaneous Water Heaters ≤ 200,000 Btu/h | ≤2 gal | Very low | UEF = 0.80 |
| All other | UEF = 0.81 |
| Commercial Gas Instantaneous Water Heaters> 200,000 Btu/h | <10 gal | All | 80% Ethermal |
| ≥10 gal | All | 80% Ethermal |
| Residential Electric Storage Water Heaters≤ 75,000 Btu/h  | ≤55 gallon tanks | Very small | UEF = 0.8808 – (0.0008 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.9254 – (0.0003 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.9307 – (0.0002 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.9349 – (0.0001 \* Rated Storage Volume in Gallons) |
| >55 gallon and ≤120 gallon tanks [[2]](#footnote-2) | Very small | UEF = 1.9236 – (0.0011 \* Rated Storage Volume in Gallons) |
| Low | UEF = 2.0440 – (0.0011 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 2.1171 – (0.0011 \* Rated Storage Volume in Gallons) |
| High | UEF = 2.2418 – (0.0011 \* Rated Storage Volume in Gallons) |
| Residential Electric Instantaneous Water Heaters  | ≤12kW and ≤2 gal | All other | UEF = 0.91 |
| High | UEF = 0.92 |
| Residential-duty CommercialElectric Instantaneous Water Heaters | > 12kW and ≤58.6 kW and ≤2 gal | All | UEF = 0.80 |

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[[3]](#footnote-3)

| **Storage Water Heater Draw Pattern** |
| --- |
| **Draw Pattern** | **First Hour Rating (gallons)** |
| Very Small | ≥ 0 and < 18 |
| Low | ≥ 18 and < 51 |
| Medium | ≥ 51 and < 75 |
| High | ≥ 75 |

| **Instantaneous Water Heater Draw Pattern** |
| --- |
| **Draw Pattern** | **Max GPM** |
| Very Small | ≥ 0 and < 1.7 |
| Low | ≥ 1.7 and < 2.8 |
| Medium | ≥ 2.8 and < 4 |
| High | ≥ 4 |

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 15 years for storage units [[4]](#footnote-4), 5 years for electric tankless,[[5]](#footnote-5) and 20 years for gas tankless.[[6]](#footnote-6)

###### Deemed Measure Cost

The full install cost and incremental cost assumptions are provided below. Actual costs should be used where available:

Gas storage water heaters:[[7]](#footnote-7)

| **Equipment Type** | **Category** | **Install Cost** | **Incremental Cost** |
| --- | --- | --- | --- |
| Gas Storage Water Heaters≤ 75,000 Btu/h, ≤55 Gallons | Baseline | $616 | N/A |
| Efficient | $1,055 | $440 |
| Gas Storage Water Heaters> 75,000 Btu/h | 0.80 Et | $4,886 | N/A |
| 0.83 Et | $5,106 | $220 |
| 0.84 Et | $5,299 | $413 |
| 0.85 Et | $5,415 | $529 |
| 0.86 Et | $5,532 | $646 |
| 0.87 Et | $5,648 | $762 |
| 0.88 Et | $5,765 | $879 |
| 0.89 Et | $5,882 | $996 |
| 0.90 Et | $6,021 | $1,135 |

For electric water heaters, the incremental capital cost for this measure is assumed to be:[[8]](#footnote-8)

|  |  |
| --- | --- |
| **Tank Size** | **Incremental Cost** |
| 50 gallons | $1050 |
| 80 gallons | $1050 |
| 100 gallons | $1950 |

The incremental capital cost for an electric tankless heater this measure is assumed to be:[[9]](#footnote-9)

| **Output (gpm) at delta T 70** | **Incremental Cost** |
| --- | --- |
| 5 | $1050 |
| 10 | $1050 |
| 15 | $1950 |

The incremental capital cost for a gas fired tankless heater is assumed to be $2,526.[[10]](#footnote-10)

###### Loadshape

For electric hot water heaters, use Loadshape C02 - Commercial Electric DHW.

###### Coincidence Factor

The coincidence factor is assumed to be 0.925.[[11]](#footnote-11)

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

Electric energy savings are calculated for electric water heaters per the equations given below.

Electric units ≤12 kW:

Where:

Tout = Tank temperature

 = 125°F

Tin = Incoming water temperature from well or municiple system

 = 54°F [[12]](#footnote-12)

HotWaterUseGallon = Estimated annual hot water consumption (gallons)

 = Actual if possible to provide reasonable custom estimate. If not, two methodologies are provided to develop an estimate:

1. Consumption per usable storage tank capacity

= Capacity \* Consumption/cap

Where:

Capacity = Usable capacity of hot water storage tank in gallons

 = Actual

Consumption/cap = Estimate of consumption per gallon of usable tank capacity, based on building type:[[13]](#footnote-13)

| **Building Type[[14]](#footnote-14)** | **Consumption/Cap** |
| --- | --- |
| Convenience | 528 |
| Education | 568 |
| Grocery | 528 |
| Health | 788 |
| Large Office | 511 |
| Large Retail | 528 |
| Lodging | 715 |
| Other Commercial | 341 |
| Restaurant | 622 |
| Small Office | 511 |
| Small Retail | 528 |
| Warehouse | 341 |
| Nursing | 672 |
| Multi-Family | 894 |

1. Consumption per unit area by building type

= (Area/1000) \* Consumption/1,000 sq.ft.

Where:

Area = Area in sq.ft that is served by DHW boiler

 = Actual

Consumption/1,000 sq.ft. = Estimate of DHW consumption per 1,000 sq.ft. based on building type:[[15]](#footnote-15)

| **Building Type[[16]](#footnote-16)** | **Consumption/1,000 sq.ft.** |
| --- | --- |
| Convenience | 4,594  |
| Education | 7,285  |
| Grocery | 697  |
| Health | 24,540  |
| Large Office | 1,818  |
| Large Retail | 1,354  |
| Lodging | 29,548  |
| Other Commercial | 3,941  |
| Restaurant | 44,439  |
| Small Office | 1,540  |
| Small Retail | 6,111  |
| Warehouse | 1,239  |
| Nursing | 30,503  |
| Multi-Family | 15,434  |

γWater = Specific weight capacity of water (lb/gal)

 = 8.33 lbs/gal

1 = Specific heat of water (Btu/lb.°F)

UEFelecbase = Rated efficiency of baseline water heater expressed as Uniform Energy Factor (UEF);

Note the same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units.

| **Equipment Type** | **Sub Category** | **Draw Pattern**  | **Federal Standard – Uniform Energy Factor[[17]](#footnote-17)** |
| --- | --- | --- | --- |
| Residential Electric Storage Water Heaters≤ 75,000 Btu/h  | ≤55 gallon tanks | Very small | UEF = 0.8808 – (0.0008 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.9254 – (0.0003 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.9307 – (0.0002 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.9349 – (0.0001 \* Rated Storage Volume in Gallons) |
| >55 gallon and ≤120 gallon tanks [[18]](#footnote-18) | Very small | UEF = 1.9236 – (0.0011 \* Rated Storage Volume in Gallons) |
| Low | UEF = 2.0440 – (0.0011 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 2.1171 – (0.0011 \* Rated Storage Volume in Gallons) |
| High | UEF = 2.2418 – (0.0011 \* Rated Storage Volume in Gallons) |
| Residential Electric Instantaneous Water Heaters  | ≤12kW and ≤2 gal | All other | UEF = 0.91 |
| High | UEF = 0.92 |
| Residential-duty CommercialElectric Instantaneous Water Heaters | > 12kW and ≤58.6 kW and ≤2 gal | All | UEF = 0.80 |

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[[19]](#footnote-19)

| **Storage Water Heater Draw Pattern** |
| --- |
| **Draw Pattern** | **First Hour Rating (gallons)** |
| Very Small | ≥ 0 and < 18 |
| Low | ≥ 18 and < 51 |
| Medium | ≥ 51 and < 75 |
| High | ≥ 75 |

| **Instantaneous Water Heater Draw Pattern** |
| --- |
| **Draw Pattern** | **Max GPM** |
| Very Small | ≥ 0 and < 1.7 |
| Low | ≥ 1.7 and < 2.8 |
| Medium | ≥ 2.8 and < 4 |
| High | ≥ 4 |

UEFeff = Rated efficiency of efficient water heater expressed as Uniform Energy Factor (UEF)

= Actual

 3412 = Converts Btu to kWh

**For example,** for a 50 gallon, 95% UEF storage unit installed in a 1500 ft2 restaurant:

ΔkWh = ((125 – 54) \* ((1,500/1,000) \* 44,439) \* 8.33 \* 1 \* (1/0.88 - 1/0.95))/3412

= 967 kWh

Electric units > 12kW:

Tair = Ambient Air Temperature

 = 70°F

V = Rated tank volume in gallons

 = Actual

SLelecbase = Standby loss of electric baseline unit (%/hr)

 = 0.30 + 27/V

 SLeff = Nameplate standby loss of new water heater, in BTU/h

8766 = Hours per year

 **For example**, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

 SLbase = 0.3 + (27 / 100)

 = 0.57%/hr

ΔkWh = (((125 – 70) \* 100 \* 8.33 \* 1 \* (0.57- 0.5)/100) \* 8766)/3412

= 82.4 kWh

###### Summer Coincident Peak Demand Savings

Where:

Hours = Full load hours of water heater

 = 6461 [[20]](#footnote-20)

CF = Summer Peak Coincidence Factor for measure

 = 0.925 [[21]](#footnote-21)

 **For example**, >12kW, 100 gallon storage unit with rated standby loss of 0.5 %/hr:

 ΔkW = 82.4 / 6,461 \* 0.925

 = 0.0118 kW

###### Natural Gas Energy Savings

Natural gas energy savings are calculated for natural gas storage water heaters per the equations given below.

Where:

100,000 = Converts Btu to Therms

EFgasbase = Rated efficiency of baseline water heater (expressed as Uniform Energy Factor (UEF) or Thermal Efficiency as provided below).

Note the same draw pattern (very small, low, medium and high draw) should be used for both baseline and efficient units.

| **Equipment Type** | **Sub Category** | **Draw Pattern**  | **Federal Standard – Uniform Energy Factor[[22]](#footnote-22)** |
| --- | --- | --- | --- |
| ResidentialGas Storage Water Heaters ≤75,000 Btu/h | ≤55 gallon tanks | Very small | UEF = 0.3456 – (0.0020 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.5982 – (0.0019 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.6483 – (0.0017 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.6920 – (0.0013 \* Rated Storage Volume in Gallons) |
| >55 gallon and ≤100 gallon tanks | Very small | UEF = 0.6470 – (0.0006 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.7689 – (0.0005 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.7897 – (0.0004 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.8072 – (0.0003 \* Rated Storage Volume in Gallons) |
| Residential-duty CommercialHigh Capacity Storage Gas-Fired Storage Water Heaters > 75,000 Btu/h | ≤120 gallon tanks  | Very small | UEF = 0.2674 – (0.0009 \* Rated Storage Volume in Gallons) |
| Low | UEF = 0.5362 – (0.0012 \* Rated Storage Volume in Gallons) |
| Medium | UEF = 0.6002 – (0.0011 \* Rated Storage Volume in Gallons) |
| High | UEF = 0.6597 – (0.0009 \* Rated Storage Volume in Gallons) |
| CommercialGas Storage Water Heaters >75,000 Btu/h and ≤155,000 Btu/h | >120 gallon tanks | All | 80% Ethermal, Standby Losses = (Q /800 + 110√Rated Storage Volume in Gallons) |
| CommercialGas Storage Water Heaters >155,000 Btu/h |  |
| Residential Gas Instantaneous Water Heaters ≤ 200,000 Btu/h | ≤2 gal | Very low | UEF = 0.80 |
| All other | UEF = 0.81 |
| Commercial Gas Instantaneous Water Heaters> 200,000 Btu/h | <10 gal | All | 80% Ethermal |
| ≥10 gal | All | 78% Ethermal |

Draw patterns are based on first hour rating (gallons) for storage tanks and maximum flow (GPM) for instantaneous as shown below:[[23]](#footnote-23)

| **Storage Water Heater Draw Pattern** |
| --- |
| **Draw Pattern** | **First Hour Rating (gallons)** |
| Very Small | ≥ 0 and < 18 |
| Low | ≥ 18 and < 51 |
| Medium | ≥ 51 and < 75 |
| High | ≥ 75 |

| **Instantaneous Water Heater Draw Pattern** |
| --- |
| **Draw Pattern** | **Max GPM** |
| Very Small | ≥ 0 and < 1.7 |
| Low | ≥ 1.7 and < 2.8 |
| Medium | ≥ 2.8 and < 4 |

**Additional Standby Loss Savings**

Gas Storage Water Heaters >75,000 Btu/h can claim additional savings due to lower standby losses.

Where:

 SLgasbase = Standby loss of gas baseline unit (Btu/h)

 Q = Nameplate input rating in Btu/h

 V = Rated volume in gallons

SLeff = Nameplate standby loss of new water heater, in Btu/h

8766 = Hours per year

 **For example**, for a 200,000 Btu/h, 150 gallon, 90% UEF storage unit with rated standby loss of 1029 BTU/h installed in a 1500 ft2 restaurant:

ΔTherms = ((125 – 54) \* ((1,500/1,000) \* 44,439) \* 8.33 \* 1 \* (1/0.8 - 1/0.9))/100,000

= 54.8 Therms

ΔThermsStandby = (((200000/800 + 110 \* √150) – 1029) \* 8766)/100,000

= 49.8 Therms

 ΔThermsTotal = 54.8 + 49.8

 = 104.6 Therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

The deemed O&M cost adjustment for a tankless heaters is $100.[[24]](#footnote-24)

###### Measure Code: CI-HWE-STWH-V07-210101

###### Review Deadline: 1/1/2024

## HVAC End Use

Many of the commercial HVAC measures use equivalent full load hours (EFLH) to calculate heating and cooling savings. The tables with these values are included in this section and referenced in each measure.

To calculate the updated EFLHs by building type and climate zone provided below, most of the eQuest models that were previously develop by a TAC Subcommittee utilizing building energy models originally developed for ComEd[[25]](#footnote-25), were migrated to OpenStudio by a parametric calibration process.  The parametric runs were controlled with a genetic learning algorithm to characteristically adjust the seed models to achieve an acceptable target error against the existing eQuest model population.  The breadth of the characteristic variations were informed through a sensitivity analysis, the IL joint assessment survey, and the existing eQuest models.  The DOE prototypical models served as the initial seed model for most instances of calibration except were a direct map to available prototypes was unavailable.

The building characteristics of the eQuest models can be found in the reference table named “EFLH Building Descriptions Updated 2014-11-21.xlsx”. The OpenStudio models are based upon the DOE Prototypes described in NREL’s “U.S. Department of Energy Commercial Reference Building Models of the National Building Stock” and a calibration log file that documents all of the variations made to each model to get them calibrated is provided in “IL-Calibration-Log\_2019-08-27.xlsx”. These documents and all the models are all available on the SharePoint site.

Note where a measure installation is within a building or application that does not fit with any of the defined building types below, the user should apply custom assumptions where it is reasonable to estimate them, else the building of best fit should be utilized.

Equivalent Full Load Hours for Heating (EFLHHeating) for Existing Buildings:

| **Building Type** | **Heating EFLH Existing Buildings** | **Model Source** |
| --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |  |
| Assembly | 1,787 | 1,831 | 1,635 | 1,089 | 1,669 | eQuest |
| Assisted Living | 1,683 | 1,646 | 1,446 | 1,063 | 1,277 | eQuest |
| Auto Dealership | 2,981 | 2,950 | 2,694 | 2,368 | 2,437 | OpenStudio |
| College | 1,256 | 1,293 | 1,138 | 1,116 | 1,131 | OpenStudio |
| Convenience Store | 1,481 | 1,368 | 1,214 | 871 | 973 | eQuest |
| Drug Store | 2,848 | 2,947 | 2,568 | 2,362 | 2,516 | OpenStudio |
| Elementary School | 1,614 | 1,603 | 1,409 | 1,209 | 1,269 | OpenStudio |
| Emergency Services | 2,757 | 2,670 | 2,383 | 2,149 | 2,186 | OpenStudio |
| Garage | 985 | 969 | 852 | 680 | 752 | eQuest |
| Grocery | 1,467 | 1,551 | 1,364 | 1,367 | 1,375 | OpenStudio |
| Healthcare Clinic | 1,446 | 1,526 | 1,452 | 1,553 | 1,574 | OpenStudio |
| High School | 1,807 | 1,855 | 1,649 | 1,591 | 1,622 | OpenStudio |
| Hospital - CAV no econ[[26]](#footnote-26) | 1,216 | 1,220 | 1,072 | 1,001 | 1,028 | OpenStudio |
| Hospital - CAV econ[[27]](#footnote-27) | 1,387 | 1,398 | 1,252 | 1,222 | 1,269 | OpenStudio |
| Hospital - VAV econ[[28]](#footnote-28) | 665 | 697 | 628 | 646 | 615 | OpenStudio |
| Hospital - FCU | 1,622 | 1,571 | 1,374 | 1,220 | 1,281 | OpenStudio |
| Hotel/Motel | 1,597 | 1,634 | 1,468 | 1,376 | 1,451 | OpenStudio |
| Hotel/Motel - Common | 1,670 | 1,733 | 1,549 | 1,496 | 1,557 | OpenStudio |
| Hotel/Motel - Guest | 1,555 | 1,597 | 1,433 | 1,316 | 1,400 | OpenStudio |
| Manufacturing Facility | 1,048 | 1,013 | 939 | 567 | 634 | eQuest |
| MF - High Rise | 1,565 | 1,540 | 1,448 | 1,089 | 1,125 | OpenStudio |
| MF - High Rise - Common | 537 | 558 | 501 | 480 | 499 | OpenStudio |
| MF - High Rise - Residential | 1,665 | 1,666 | 1,512 | 1,145 | 1,207 | OpenStudio |
| MF - Mid Rise | 1,730 | 1,782 | 1,589 | 1,538 | 1,560 | OpenStudio |
| Movie Theater | 1,916 | 1,905 | 1,718 | 1,288 | 1,538 | eQuest |
| Office - High Rise - CAV no econ | 995 | 1,036 | 933 | 786 | 832 | OpenStudio |
| Office - High Rise - CAV econ | 1,001 | 1,051 | 929 | 803 | 851 | OpenStudio |
| Office - High Rise - VAV econ | 1,552 | 1,432 | 1,239 | 1,077 | 1,098 | OpenStudio |
| Office - High Rise - FCU | 1,015 | 993 | 899 | 773 | 809 | OpenStudio |
| Office - Low Rise | 2,825 | 2,625 | 2,365 | 2,007 | 2,040 | OpenStudio |
| Office - Mid Rise | 1,672 | 1,629 | 1,454 | 1,356 | 1,399 | OpenStudio |
| Religious Building | 1,603 | 1,504 | 1,440 | 1,054 | 1,205 | eQuest |
| Restaurant | 1,326 | 1,328 | 1,179 | 1,091 | 1,122 | OpenStudio |
| Retail - Department Store | 1,365 | 1,322 | 1,193 | 1,034 | 1,088 | OpenStudio |
| Retail - Strip Mall | 1,347 | 1,325 | 1,183 | 1,064 | 1,096 | OpenStudio |
| Warehouse | 1,285 | 1,286 | 1,180 | 1,147 | 1,224 | OpenStudio |
| Unknown | 1,709 | 1,678 | 1,508 | 1,287 | 1,411 | n/a |

Equivalent Full Load Hours for Heating (EFLHHeating) for New Construction:

| **Building Type** | **Heating EFLH New Construction** | **Model Source** |
| --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Auto Dealership | 1,286 | 1,185 | 1,279 | 1,138 | 1,078 | OpenStudio |
| College | 942 | 834 | 906 | 831 | 818 | OpenStudio |
| Drug Store | 1,023 | 930 | 1,017 | 889 | 822 | OpenStudio |
| Elementary School | 949 | 878 | 943 | 861 | 859 | OpenStudio |
| Emergency Services | 480 | 352 | 501 | 407 | 347 | OpenStudio |
| Grocery | 2,795 | 2,788 | 2,549 | 2,380 | 2,597 |  OpenStudio |
| Healthcare Clinic | 1,534 | 1,417 | 1,555 | 1,395 | 1,371 | OpenStudio |
| High School | 1,502 | 1,549 | 1,368 | 1,283 | 1,299 | OpenStudio  |
| Hospital - CAV no econ | 2,345 | 2,207 | 2,318 | 2,110 | 2,195 | OpenStudio |
| Hospital - CAV econ | 2,345 | 2,207 | 2,318 | 2,110 | 2,195 | OpenStudio |
| Hospital - VAV econ | 2,345 | 2,207 | 2,318 | 2,110 | 2,195 | OpenStudio |
| Hospital - FCU | 2,345 | 2,207 | 2,318 | 2,110 | 2,195 | OpenStudio |
| Hotel/Motel - Residential | 1,412 | 1,243 | 1,439 | 1,405 | 1,146 | OpenStudio |
| Hotel\_Motel\_Common | 1,554 | 1,415 | 1,519 | 1,410 | 1,361 | OpenStudio |
| Hotel\_Motel\_Guest | 1,538 | 1,083 | 1,554 | 1,381 | 987 | OpenStudio |
| MF - High Rise | 1,308 | 884 | 1,361 | 1,125 | 865 | OpenStudio |
| MF - High Rise - Common | 1,581 | 1,280 | 1,590 | 1,349 | 1,220 | OpenStudio |
| MF - High Rise - Residential | 1,352 | 946 | 1,413 | 1,174 | 917 | OpenStudio |
| MF - Mid Rise | 1,637 | 1,385 | 1,637 | 1,434 | 1,322 | OpenStudio |
| Office - High Rise - FCU | 987 | 870 | 1,001 | 893 | 837 | OpenStudio |
| Office - High Rise - VAV econ | 987 | 870 | 1,001 | 893 | 837 | OpenStudio |
| Office - Mid Rise | 867 | 759 | 892 | 792 | 701 | OpenStudio |
| Office - High Rise - CAV no econ | 967 | 854 | 971 | 876 | 804 | OpenStudio |
| Office Low Rise | 954 | 916 | 826 | 667 | 664 | OpenStudio |
| Restaurant | 787 | 797 | 671 | 811 | 820 | OpenStudio |
| Retail - Department Store | 1,286 | 1,185 | 1,279 | 1,138 | 1,078 | OpenStudio |
| Retail - Strip Mall | 973 | 867 | 972 | 857 | 777 | OpenStudio |
| Warehouse | 1,413 | 1,390 | 1,398 | 1,298 | 1,290 | OpenStudio |
| Unknown | 1,133 | 1,064 | 1,091 | 982 | 960 | n/a |

Equivalent Full Load Hours for Cooling (EFLHcooling) for Existing Buildings:

| **Building Type** | **Cooling EFLH Existing Buildings** | **Model Source** |
| --- | --- | --- |
| **Zone 1 (Rockford)** | **Zone 2 (Chicago)** | **Zone 3 (Springfield)** | **Zone 4 (Belleville)** | **Zone 5 (Marion)** |
| Assembly | 725 | 796 | 937 | 1,183 | 932 | eQuest |
| Assisted Living | 1,475 | 1,457 | 1,773 | 2,110 | 1,811 | eQuest |
| Auto Dealership | 996 | 1,051 | 1,343 | 1,582 | 1,414 | OpenStudio |
| College | 572 | 564 | 676 | 776 | 613 | OpenStudio |
| Convenience Store | 1,088 | 1,067 | 1,368 | 1,541 | 1,371 | eQuest |
| Drug Store | 858 | 943 | 1,133 | 1,279 | 1,092 | OpenStudio |
| Elementary School | 834 | 837 | 999 | 1264 | 967 | OpenStudio |
| Emergency Services | 2,983 | 3,009 | 3,762 | 4,030 | 3,740 | OpenStudio |
| Garage | 934 | 974 | 1,226 | 1,582 | 1,383 | eQuest |
| Grocery | 826 | 914 | 1,151 | 1,329 | 1,240 | OpenStudio |
| Healthcare Clinic | 1,220 | 1,294 | 1,505 | 1,658 | 1,534 | OpenStudio |
| High School | 892 | 883 | 1,066 | 1,397 | 1,018 | OpenStudio |
| Hospital - CAV no econ | 1,719 | 1,799 | 2,068 | 2,238 | 2,066 | OpenStudio |
| Hospital - CAV econ | 1,267 | 1,302 | 1,604 | 1,798 | 1,592 | OpenStudio |
| Hospital - VAV econ | 3,313 | 3,332 | 3,458 | 3,546 | 3,311 | OpenStudio |
| Hospital - FCU | 1,575 | 1,562 | 1,921 | 1,979 | 1,812 | OpenStudio |
| Hotel/Motel | 1,106 | 1,148 | 1,453 | 1,605 | 1,435 | OpenStudio |
| Hotel/Motel - Common | 1,108 | 1,168 | 1,430 | 1,574 | 1,406 | OpenStudio |
| Hotel/Motel - Guest | 1,061 | 1,106 | 1,391 | 1,509 | 1,401 | OpenStudio |
| Manufacturing Facility | 1,010 | 1,055 | 1,209 | 1,453 | 1,273 | eQuest |
| MF - High Rise | 928 | 920 | 1,059 | 1,360 | 1,205 | OpenStudio |
| MF - High Rise - Common | 1,405 | 1,383 | 1,479 | 1,527 | 1,466 | OpenStudio |
| MF - High Rise - Residential | 764 | 807 | 976 | 1,216 | 1,147 | OpenStudio |
| MF - Mid Rise | 787 | 855 | 1,099 | 1,198 | 1,082 | OpenStudio |
| Movie Theater | 876 | 745 | 1,036 | 1,178 | 1,010 | eQuest |
| Office - High Rise - CAV no econ | 1,357 | 1,404 | 1,587 | 1,753 | 1,468 | OpenStudio |
| Office - High Rise - CAV econ | 922 | 937 | 1,138 | 1,274 | 1,000 | OpenStudio |
| Office - High Rise - VAV econ | 847 | 887 | 991 | 1,092 | 893 | OpenStudio |
| Office - High Rise - FCU | 1,083 | 1,116 | 1,269 | 1,348 | 1,266 | OpenStudio |
| Office - Low Rise | 1,796 | 1,790 | 2,233 | 2,342 | 2,219 | OpenStudio |
| Office - Mid Rise | 1,128 | 1,153 | 1,360 | 1,461 | 1,356 | OpenStudio |
| Religious Building | 861 | 817 | 967 | 1,159 | 1,067 | eQuest |
| Restaurant | 990 | 1,021 | 1,273 | 1,411 | 1,290 | OpenStudio |
| Retail - Department Store | 639 | 640 | 775 | 936 | 812 | OpenStudio |
| Retail - Strip Mall | 697 | 720 | 915 | 998 | 930 | OpenStudio |
| Warehouse | 252 | 265 | 363 | 377 | 379 | OpenStudio |
| Unknown | 1,003 | 1,019 | 1,230 | 1,403 | 1,236 | n/a |

### Steam Trap Replacement or Repair

###### Description

The measure applies to the repair or replacement of steam traps in the failed open state that allow steam to escape the steam distribution system or return to the condensate receiver leading to increased steam generation. The measure is applicable to commercial applications, commercial HVAC (low pressure steam) including multifamily buildings, low pressure industrial applications, medium pressure industrial applications, applications and high-pressure industrial applications.

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

###### Definition of Efficient Equipment

Customers must have steam traps in the failed open or leaking state to qualify for rebates. However, if a commercial customer opts to replace all traps without inspection, rebates and the savings are discounted to take into consideration the fact that some traps are being replaced that have not yet failed.

###### Definition of Baseline Equipment

The baseline criterion is a faulty steam trap in the failed open or leaking state. No minimum leak rate is required. Any leaking or blow through trap can be repaired or replaced. If a commercial customer chooses to repair or replace all the steam traps at the facility without verification, the savings are adjusted. Savings for commercial full replacement projects are reduced by the percentage of traps found to be leaking on average from the studies listed. If an audit is performed on a commercial site, then the leaking and blowdown can be adjusted.

###### Deemed Lifetime of Efficient Equipment

For standard steam traps the life of this measure is 6 years.[[29]](#footnote-29)

For Venturi steam traps the measure life is 20 years if replacing a faulty mechanical steam trap.[[30]](#footnote-30) If replacing an operational mechanical steam trap, the measure life is 14 years, having been reduced by the six-year measure life established for the Steam Trap Replacement or Repair measure from the IL TRM. By applying this conservative approach of reducing the measure life by the full estimated useful life of the existing steam trap, there is no need to survey or produce an inventory of the age of existing steam traps.

Venturi steam traps do not contain any moving parts, and their manufacturers cite this feature for the reduced failure rate leading to longer operational life than mechanical steam traps. Venturi steam traps have been observed to operate in excess of 20 years.[[31]](#footnote-31) Venturi steam traps also typically come with a 10-year warranty that can be extended up to 20 years. Therefore, savings may be claimed on a year-to-year basis for venturi steam traps undergoing annual maintenance that have exhausted their deemed 20-year measure life.

###### Deemed Measure Cost

| **Steam System** | **Cost per trap**[[32]](#footnote-32) **($)** |
| --- | --- |
| Commercial Dry Cleaners | 77 |
| Commercial Heating (including Multifamily), low pressure steam | 77 |
| Industrial Medium Pressure >15 psig, < 30 psig | 180 |
| Steam Trap, Industrial Medium Pressure ≥30 <75 psig | 223 |
| Steam Trap, Industrial High Pressure ≥75 <125 psig | 276 |
| Steam Trap, Industrial High Pressure ≥125 <175 psig | 322 |
| Steam Trap, Industrial High Pressure ≥175 <250 psig | 370 |
| Steam Trap, Industrial High Pressure ≥250 psig | 418 |

###### Loadshape

N/A

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Savings

###### Energy Savings

###### Electric Energy Savings

Secondary kWh Savings for Water Supply and Wastewater Treatment

The following savings should be included in the total savings for this measure but should not be included in TRC tests to avoid double counting the economic benefit of water savings. These savings only apply to situations in which steam is lost from the steam system.

ΔkWhwater = ΔWater (gallons) / 1,000,000 \* Ewater supply

Where

Ewater supply = Water Supply Energy Factor (kWh/Million Gallons)

 = 2,571[[33]](#footnote-33)

###### Summer Coincident Peak Demand Savings

N/A

###### Natural Gas Savings

ΔTherm = Sa \* (Hv + Hs \* (T1 - Tsource)) \* Hours \* L / (100,000 \* ηB)

Where:

Sa = Steam loss per leaking trap (lbs/hr)

For systems used in space heating applications that operate at 5 psig or lower, use the following equation to calculate Sa[[34]](#footnote-34). The condensate return system pressure, P2, will typically be atmospheric pressure, 14.696 psia.

 Sa = 1519.3 \* P1 \* D2 \* [(1/T1) \* (γ/(γ-1)) \* ((P2/P1)(2/γ) - (P2/P1)((γ+1)/γ))]0.5 \* A \* FF

For all other steam systems and applications, use the following equation.

Sa = 24.24 \* P1 \* D2 \* A \* FF

Defaults are provided in table below if custom calculation is not performed.

Where:

1519.3 = Constant, (s2 \* °R0.5)/(ft \* hr)

P1 = Average steam trap inlet pressure (absolute, psia). If not available, use defaults provided in table below (note that defaults are provided in psig, not psia).

D = Diameter of orifice, inches. Actual value should be used wherever possible as this value has a significant impact on steam flowrate value.

T1 = Temperature of Saturated Steam (°R)

 = 507.89 \* P10.0962

 Where:

 507.89 = Constant, °R\*(in2/lbf)0.0962

= Heat Capacity Ratio (unitless)

 = 5.071 \* 10-4 \* P1 + 1.332

P2 = Average steam trap outlet pressure (absolute psia). If unknown, assume atmospheric pressure, 14.696 psia.

A = Adjustment factor

= 50%,[[35]](#footnote-35) all steam systems. This factor accounts for reduction in the maximum theoretical steam flow to the average steam flow (the Enbridge factor).

FF = Flow Factor. In addition to the Adjustment factor (A), an additional 50 percent flow factor adjustment is recommended for medium and high-pressure steam systems to address industrial float and thermostatic style traps where additional blockage is possible.

24.24 = Constant lbm/(hr-psia-in2)

Default Steam Loss per Trap (Sa) are provided below for different system types:

| **Steam System** | **Average Steam Trap Inlet Pressure psig**[[36]](#footnote-36) | **Diameter of Orifice in** | **Adjustment Factor** | **Flow Factor** | **Average Actual Steam Loss per Leaking Trap (lbm/hr/trap) [[37]](#footnote-37)** |
| --- | --- | --- | --- | --- | --- |
| Commercial Dry Cleaners | 82.8 | 0.125 | 50% | 100% | 18.5 |
| Multifamily LPS Space Heating - calculate Sa as provided above. If using default value, cap total savings at 20% of building consumption | - | - | 50% | 100% | 6.9 |
| Commercial LPS Space Heating  | - | - | 50% | 100% | 6.9 |
| Industrial or Process Low Pressure, <15 psig | - | - | 50% | 100% | 6.9 |
| Medium Pressure >15 psig < 30 psig | 16 | 0.1875 | 50% | 50% | 6.5 |
| Medium Pressure ≥30 <75 psig | 47 | 0.2500 | 50% | 50% | 23.4 |
| High Pressure ≥75 <125 psig | 101 | 0.2500 | 50% | 50% | 43.8 |
| High Pressure ≥125 <175 psig | 146 | 0.2500 | 50% | 50% | 60.9 |
| High Pressure ≥175 <250 psig | 202 | 0.2500 | 50% | 50% | 82.1 |
| High Pressure ≥250 ≤300 psig | 263 | 0.2500 | 50% | 50% | 105.2 |
| High Pressure > 300 psig | Custom | Custom  | 50% | 50% | Calculated |

Hv = Heat of vaporization of steam, (Btu/lbm)

|  |  |  |
| --- | --- | --- |
| **Steam System** | **Average Inlet Pressure psig** | **Heat of Vaporization**[[38]](#footnote-38) **(Btu/lbm)** |
| Commercial Dry Cleaners | -- | 890 |
| Commercial Space Heating (including Multifamily) LPS  | -- | 951 |
| Industrial and Process Low Pressure ≤15 psig | -- | 951 |
| Medium Pressure >15 psig < 30 psig | 16 | 944 |
| Medium Pressure ≥30 <75 psig | 47 | 915 |
| High Pressure ≥75 <125 psig | 101 | 880 |
| High Pressure ≥125 <175 psig | 146 | 859 |
| High Pressure ≥175 <250 psig | 202 | 837 |
| High Pressure ≥250 ≤300 psig  | 263 | 816 |
| High Pressure > 300 psig | -- | Custom |

Hs = Specfic heat of water, (Btu/(lbm \* °R))

 = 1.001

Tsource = Incoming water temperature

 = 513.67°R[[39]](#footnote-39)

ηB = Boiler efficiency

= custom, if unknown:

= 80.7% for steam boilers, except multifamily low-pressure [[40]](#footnote-40)

= 64.8% for multifamily low-pressure steam boilers [[41]](#footnote-41)

Hours = Annual hours when steam system is pressurized

= custom, if unknown:

| **Steam System** | **Zone (where applicable)** | **Hours/Yr**[[42]](#footnote-42) |
| --- | --- | --- |
| Commercial Dry Cleaners | All Climate Zones | 2,425 |
| Industrial and Process Low Pressure ≤15 psig | 8,282 |
| Medium Pressure >15 psig < 30 psig | 8,282 |
| Medium Pressure ≥30 <75 psig | 8,282 |
| High Pressure ≥75 <125 psig | 8,282 |
| High Pressure ≥125 <175 psig | 8,282 |
| High Pressure ≥175 <250 psig | 8,282 |
| High Pressure ≥250 psig | 8,282 |
| Commercial Space Heating LPS  | Rockford | 4,272 |
| Chicago | 4,029 |
| Springfield | 3,406 |
| Belleville | 2,515 |
| Marion | 2,546 |
| Multifamily Space Heating LPS | For steam traps that are part of steam systems where the boiler cycles on/off to maintain space setpoint temperature or for steam traps located downstream of a steam control valve that opens/closes to maintain setpoint temperature, use Heating EFLH values in Section 4.4 for High Rise or Mid-Rise MF buildings.For steam traps that are exposed to steam continuously throughout the heating season, use the values listed above for Commercial Space Heating LPS for your appropriate climate zone. |

L = Leaking & blow-thru

L is 1.0 when applied to the replacment of an individual leaking trap. If a number of steam traps are replaced and the system has not been audited, the leaking and blow-thru is applied to reflect the assumed percentage of steam traps that were actually leaking and need to be replaced. A custom value can be utilized if a supported by an evaluation.

| **Steam System** | **L (%)**[[43]](#footnote-43) |
| --- | --- |
| Custom | Custom |
| Commercial Dry Cleaners | 27% |
| Commercial Heating (including Multifamily) LPS  | 27% |
| Industrial and Process Low Pressure ≤15 psig | 16% |
| Medium Pressure >15 psig < 30 psig | 16% |
| Medium Pressure ≥30 <75 psig | 16% |
| High Pressure ≥75 <125 psig | 16% |
| High Pressure ≥125 <175 psig | 16% |
| High Pressure ≥175 <250 psig | 16% |
| High Pressure > 300 psig | 16% |

**For example**, a commercial dry cleaning facility with the default hours of operation and boiler efficiency;

ΔTherms = Sa \* (Hv + Hs \* (T1 - Tsource)) \* Hours \* L / (100,000 \* ηB)

T1 = 507.89 \* P10.0962

= 507.89 \* (82.8 + 14.696)0.0962

= 789.1°R

ΔTherms = 18.5 lbs/hr/trap \* (890 Btu/lb + 1.001 \* (789.1°R - 513.7°R)) \* 2,425hrs \* 27%/(100,000 \* 80.7%)

= 175.0 therms per trap

###### Water Impact Descriptions and Calculation

The hourly water volume saved per each repaired or replaced leaking trap is calculated by dividing the “Average Actual Steam Loss per Leaking Trap (lbm/hr/trap)” by the density of water saved, 8.33 lbm/gal, that replaces the lost steam. The average actual steam loss is provided in the table for parameter *Sa*, the “Average actual steam loss per leaking trap” in the Natural Gas savings section above. Annual water savings are calculated using *Hours* and *L*, the leaking and blow through factor, as defined above.

Water savings only apply to situations where condensate is lost from the steam system. If a condensate recovery system is in place, assume zero water savings or provide a custom calculation based on site-specific operation.

The annual water savings for a replaced or repaired trap is given by:

ΔWater = GAL \* Hours \* L

Where:

GAL = average actual water volume saved per leaking trap, as listed in the following table and based on steam system type.

*Other variables as defined above.*

| **Steam System\*** | **Average Actual Steam Loss per Leaking Trap (lbm/hr/trap)** | **GAL: Average Actual Water Volume Saved per Leaking Trap****Atmospheric Venting****(gal/hr/trap)** |
| --- | --- | --- |
| Commercial Dry Cleaners | 19.1 | 2.29 |
| Commercial Heating (including Multifamily) LPS | 6.9 | 0.83 |
| Industrial or Process Low Pressure, <15 psig | 6.9 | 0.83 |
| Medium Pressure >15 psig < 30 psig | 6.5 | 0.78 |
| Medium Pressure ≥30 <75 psig | 23.4 | 2.81 |
| High Pressure ≥75 <125 psig | 43.8 | 5.26 |
| High Pressure ≥125 <175 psig | 60.9 | 7.31 |
| High Pressure ≥175 <250 psig | 82.1 | 9.86 |
| High Pressure ≥250 ≤300 psig | 105.2 | 12.63 |
| High Pressure > 300 psig | Calculated | Calculated Steam Loss / 8.33 |

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-STRE-V08-210101

###### Review Deadline: 1/1/2023

### Notched V Belts for HVAC Systems

###### Measure Description

This measure is for replacement of smooth v-belts in non-residential package and split HVAC systems with notched v-belts or for installing new equipment with synchronous belts instead of smooth v-belts. Typically there is a v-belt between the motor and the supply air fan and/or return air fan in larger package and split HVAC systems (RTU).

In general there are two styles of grooved v-belts, notched and synchronous. The DOE defines each as follows;

**Notched V-Belts** - A notched belt has grooves or notches that run perpendicular to the belt’s length, which reduces the bending resistance of the belt. Notched belts can use the same pulleys as cross-section standard V-belts. They run cooler, last longer, and are about 2% more efficient than standard V-belts.

**Synchronous Belts** - Synchronous belts (also called cogged, timing, positive-drive, or high-torque drive belts) are toothed and require the installation of mating grooved sprockets. These belts operate with a consistent efficiency of 98% and maintain their efficiency over a wide load range.

Smooth v-belts are usually referred to in five basic groups:

* “L” belts are low end belts that are for small, fractional horsepower motors and these are not used in RTUs.
* “A” and “B” belts are the two types typically used in RTUs. The “A” belt is a ½ inch width by 5/16 inch thickness and the “B” belt is larger, 21/32 inch wide and 12/32 inch thick so it can carry more power. V-belts come in a wide variety of lengths where 20 to 100 inches is typical.
* “C” and “D” belts are primarily for industrial applications with high power transmission requirements.
* V-belts are provided by various vendors. The notched version of these belts typically have an “X” added to the designation. For this HVAC fans notched v-belt Replacement measure, only the “A” and “B” v-belts are considered. A typical “A” v-belt is replaced by a notched “AX” v-belt and a “B” is replaced by a “BX.” In general, smooth v-belts have an efficiency of 90% to 98% while notched v-belts have an efficiency of 95% to 98%. Because notched v-belts are more flexible they work with smaller diameter pulleys and they have less resistance to bending. Lower bending resistance increases the power transmission efficiency, lowers the waste heat, and allows the belt to last longer than a smooth belt.

Three research papers[[44]](#footnote-44) [[45]](#footnote-45) [[46]](#footnote-46) show that the notched v-belt efficiency is 2% to 5% better than a typical smooth v-belt. A fourth paper by USDOE’s Energy Efficiency and Renewable Energy[[47]](#footnote-47) group reviewed most of the earlier literature and recommended using a conservative 2% efficiency improvement for energy savings for calculations.

For this measure it is assumed that upgrading a standard smooth v-belt with a new notched v-belt will result in a fan energy reduction of 2%.

###### Definition of Efficient Equipment

For the Notched V-Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have notched v-belts installed on the supply and/or return air fans. This can be done as a retrofit, TOS, or NC project.

For the Synchronous Belt characterization to apply, the Efficient Equipment is HVAC RTUs that have synchronous belts installed on the supply and/or return air fans. This can be done as a TOS or NC project. Retrofit projects can also claim savings, but costs should be verified independently (typically the cost of installing synchronous belts as a retrofit is not economically viable).

###### Definition of Baseline Equipment

The Baseline Equipment is HVAC RTUs that have smooth v-belts installed on the supply and/or return air fans (i.e., RTU does not already have a notched v-belt installed).

###### Deemed Lifetime of Efficient Equipment

A v-belt has a life based on fan run hours which varies by building type based primarily on occupancy schedule because the fans are required by code to operate continuously during occupied hours. The supply and return fans will also run a few hours during unoccupied hours for heating and cooling as needed. For the notched v-belt EUL calculation, the default hours in the following table are used for a variety of building types and HVAC applications.[[48]](#footnote-48)

EUL = Belt Life / Occupancy Hours per year

Where:

Belt Life = 24,000 hours[[49]](#footnote-49)

Occupancy Hours per year = values from Table below

The notched v-belt measure EUL is summarized by building type in the following table.

**Notched v-belt Effective Useful Life (EUL)**

| **Building Type** | **Total Fan Run Hours** | **EUL (Years)** | **Model Source** |
| --- | --- | --- | --- |
| Assembly | 7235 | 3.3 | eQuest |
| Assisted Living | 8760 | 2.7 | eQuest |
| Auto Dealership | 7451 | 3.2 | OpenStudio |
| College | 4836 | 5.0 | OpenStudio |
| Convenience Store | 7004 | 3.4 | eQuest |
| Drug Store | 7156 | 3.4 | OpenStudio |
| Elementary School | 3765 | 6.4 | OpenStudio |
| Emergency Services | 8760 | 2.7 | OpenStudio |
| Garage | 7357 | 3.3 | eQuest |
| Grocery | 8543 | 2.8 | OpenStudio |
| Healthcare Clinic | 4314 | 5.6 | OpenStudio |
| High School | 3460 | 6.9 | OpenStudio |
| Hospital - VAV econ | 4666 | 5.1 | OpenStudio |
| Hospital - CAV econ | 8021 | 3.0 | OpenStudio |
| Hospital - CAV no econ | 7924 | 3.0 | OpenStudio |
| Hospital - FCU | 4055 | 5.9 | OpenStudio |
| Manufacturing Facility | 8706 | 2.8 | eQuest |
| MF - High Rise | 8760 | 2.7 | OpenStudio |
| MF - Mid Rise | 8760 | 2.7 | OpenStudio |
| Hotel/Motel - Guest | 2409 | 10.0 | OpenStudio |
| Hotel/Motel - Common | 8683 | 2.8 | OpenStudio |
| Movie Theater | 7505 | 3.2 | eQuest |
| Office - High Rise - VAV econ | 2369 | 10.1 | OpenStudio |
| Office - High Rise - CAV econ | 2279 | 10.5 | OpenStudio |
| Office - High Rise - CAV no econ | 5303 | 4.5 | OpenStudio |
| Office - High Rise - FCU | 1648 | 14.6 | OpenStudio |
| Office - Low Rise | 6345 | 3.8 | OpenStudio |
| Office - Mid Rise | 3440 | 7.0 | OpenStudio |
| Religious Building | 7380 | 3.3 | eQuest |
| Restaurant | 7302 | 3.3 | OpenStudio |
| Retail - Department Store | 7155 | 3.4 | OpenStudio |
| Retail - Strip Mall | 6921 | 3.5 | OpenStudio |
| Warehouse | 6832 | 3.5 | OpenStudio |
| Unknown | 6241 | 3.8 | n/a |

The lifetime of a synchronous belt system is the same as the lifetime of the equipment it is installed on because it is a permanent upgrade, involving the installation of toothed pulleys. Typical HVAC RTU lifetime is 15 years, which applies to synchronous belts as well. This is not to suggest that the actual belt component has an equivalent lifetime because they do require replacement. However, their O&M cost savings (derived from not having to tension, etc.) are assumed to offset the replacement cost of the belt, resulting in a net cost of zero. As a result, neither a separate lifetime nor O&M savings are quantified for synchronous belts and lifetime can therefore be considered as the lifetime of the equipment they’re installed on because it would not be possible to install a traditional or notched belt on the synchronous pulleys.

###### Deemed Measure Cost

A review of the Grainger online pricing for “A,” “B,” “AX,” and “BX” v-belts[[50]](#footnote-50) showed the incremental cost to upgrade to notched v-belts would result in a 28% price increase. The notched v-belt incremental cost is summarized in the table below:

**Notched V-belt Incremental Cost Summary**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Smooth V-Belt Industry Number** | **Outside Length (Inches)** | **Dayton Smooth V-Belt\*** | **Notched V-belt Industry Number** | **Dayton Notched v-belt\*** | **Price Increase** | **% Increase** |
| A30 (Item # 1A095) | 32 | $12.70 | AX29 (Item # 3GWU4) | $17.65 | $4.95 | 28% |
| B29 (Item # 6L208) | 32 | $16.75 | BX29 (Item # 5TXL4) | $23.23 | $6.48 | 28% |
| \* Pricing based on Dayton Belts as found on Grainger Website 10/30/14 |

Note that the incremental cost for notched V-Belts assumes that the notched belt is purchased and installed instead of a smooth v-belt. There is no difference in the cost of installation, only the material.

**Synchronous Belt Incremental Cost Summary**

| **Smooth V-Belt Industry Number** | **Smooth belt system Price\*** | **Synchronous Belt Industry Number** | **Synchronous System Price\*** | **Price Difference** |
| --- | --- | --- | --- | --- |
| Belt A30 (Item # 1A095) | $12.70 | Belt 1DHL5 (Item # 322L050) | $20.51 | $7.81 |
| Gearbelt pulley BK47 (Item #5UHD5) | $45.90 | Gearbelt sprocketGTR-36G-8M-12 (Item # 2UWH6) | $113.00 | $67.10 |
| \* Costs based on Grainger pricing. |

Incremental cost for a NC or TOS project is $142. This is the price of synchronous equipment (belt, two sprockets) subtract v-belt equipment (belt, two pulleys). Labor cost is assumed to be equal in the baseline and efficient cases.

Incremental cost for a RF project is $383.81. This is the price of synchronous equipment and labor to install it[[51]](#footnote-51) (not including a trip charge), less the cost of the v-belt (but not the pulleys).

###### Deemed O&M Cost Adjustments

N/A

###### Loadshape

Loadshape C05 - Commercial Electric Heating and Cooling

###### Coincidence Factor

N/A

**Algorithm**

###### Calculation of Energy Savings

###### Electric Energy Savings

ΔkWh = kWconnected\* Hours \* ESF

Where:

kWConnected =kW of equipment is calculated using motor efficiency[[52]](#footnote-52)

= (HP \* 0.746 kW/HP\* Load Factor)/Motor Efficiency

Load Factor =Motors are assumed to have a load factor of 80% for calculating KW if actual values cannot be determined.[[53]](#footnote-53) Custom load factor may be applied if known.

Motor Efficiency = Actual motor efficiency shall be used to calculate KW. If not known a value from the motor efficiency refrence tables below should be used.**[[54]](#footnote-54)** Default motor is a NEMA Premium Efficiency, ODP, 4-pole/1800 RPM fan motor

| **Baseline Motor Efficiencies (EPACT)** |
| --- |
| **Size HP** | **Open Drip Proof (ODP)** | **Totally Enclosed Fan-Cooled (TEFC)** |
| **# of Poles** |
| **6** | **4** | **2** | **6** | **4** | **2** |
| **Speed (RPM)** |
| **1200** | **1800** | **3600** | **1200** | **1800** | **3600** |
| 1/8 | - | 44.00% | - | - | - | - |
| 1/6 | 57.50% | 62.00% | - | - | - | - |
| 1/4 | 68.00% | 68.00% | - | 68.00% | 64.00% | - |
| 1/3 | 70.00% | 70.00% | 72.00% | 70.00% | 68.00% | 72.00% |
| 1/2 | 78.50% | 80.00% | 68.00% | 72.00% | 74.00% | 68.00% |
| 3/4 | 77.00% | 78.50% | 74.00% | 77.00% | 75.50% | 74.00% |
| 1 | 80.00% | 82.50% | 75.50% | 80.00% | 82.50% | 75.50% |
| 1.5 | 84.00% | 84.00% | 82.50% | 85.50% | 84.00% | 82.50% |
| 2 | 85.50% | 84.00% | 84.00% | 86.50% | 84.00% | 84.00% |
| 3 | 86.50% | 86.50% | 84.00% | 87.50% | 87.50% | 85.50% |
| 5 | 87.50% | 87.50% | 85.50% | 87.50% | 87.50% | 87.50% |
| 7.5 | 88.50% | 88.50% | 87.50% | 89.50% | 89.50% | 88.50% |
| 10 | 90.20% | 89.50% | 88.50% | 89.50% | 89.50% | 89.50% |
| 15 | 90.20% | 91.00% | 89.50% | 90.20% | 91.00% | 90.20% |
| 20 | 91.00% | 91.00% | 90.20% | 90.20% | 91.00% | 90.20% |
| 25 | 91.70% | 91.70% | 91.00% | 91.70% | 92.40% | 91.00% |

| **Efficient Motor Efficiencies (NEMA Premium)** |
| --- |
| **Size HP** | **Open Drip Proof (ODP)** | **Totally Enclosed Fan-Cooled (TEFC)** |
| **# of Poles** | **# of Poles** |
| **2** | **4** | **6** | **2** | **4** | **6** |
| **Speed (RPM)** | **Speed (RPM)** |
| **1200** | **1800 (Default)** | **3600** | **1200** | **1800** | **3600** |
| 0.125 \* | - | 44.00% | - | - | - | - |
| 1/6 | 57.50% | 62.00% | - | - | - | - |
| 1/4 | 68.00% | 68.00% | - | 68.00% | 64.00% | - |
| 1/3 | 70.00% | 70.00% | 72.00% | 70.00% | 68.00% | 72.00% |
| 1/2 | 78.50% | 80.00% | 68.00% | 72.00% | 74.00% | 68.00% |
| 3/4 | 77.00% | 78.50% | 74.00% | 77.00% | 75.50% | 74.00% |
| 1 | 82.50% | 85.50% | 77.00% | 82.50% | 85.50% | 77.00% |
| 1.5 | 86.50% | 86.50% | 84.00% | 87.50% | 86.50% | 84.00% |
| 2 | 87.50% | 86.50% | 85.50% | 88.50% | 86.50% | 85.50% |
| 3 | 88.50% | 89.50% | 85.50% | 89.50% | 89.50% | 86.50% |
| 5 | 89.50% | 89.50% | 86.50% | 89.50% | 89.50% | 88.50% |
| 7.5 | 90.20% | 91.00% | 88.50% | 91.00% | 91.70% | 89.50% |
| 10 | 91.70% | 91.70% | 89.50% | 91.00% | 91.70% | 90.20% |
| 15 | 91.70% | 93.00% | 90.20% | 91.70% | 92.40% | 91.00% |
| 20 | 92.40% | 93.00% | 91.00% | 91.70% | 93.00% | 91.00% |
| 25 | 93.00% | 93.60% | 91.70% | 93.00% | 93.60% | 91.70% |

Hours = When available, actual hours should be used. If actual hours are not available, default hours are provided in table below for HVAC fan operation[[55]](#footnote-55), which varies by building type:

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Total Fan Run Hours** | **Model Source** |
| Assembly | 7235 | eQuest |
| Assisted Living | 8760 | eQuest |
| Auto Dealership | 7451 | OpenStudio |
| College | 4836 | OpenStudio |
| Convenience Store | 7004 | eQuest |
| Drug Store | 7156 | OpenStudio |
| Elementary School | 3765 | OpenStudio |
| Emergency Services | 8760 | OpenStudio |
| Garage | 7357 | eQuest |
| Grocery | 8543 | OpenStudio |
| Healthcare Clinic | 4314 | OpenStudio |
| High School | 3460 | OpenStudio |
| Hospital - VAV econ | 4666 | OpenStudio |
| Hospital - CAV econ | 8021 | OpenStudio |
| Hospital - CAV no econ | 7924 | OpenStudio |
| Hospital - FCU | 4055 | OpenStudio |
| Manufacturing Facility | 8706 | eQuest |
| MF - High Rise | 8760 | OpenStudio |
| MF - Mid Rise | 8760 | OpenStudio |
| Hotel/Motel - Guest | 2409 | OpenStudio |
| Hotel/Motel - Common | 8683 | OpenStudio |
| Movie Theater | 7505 | eQuest |
| Office - High Rise - VAV econ | 2369 | OpenStudio |
| Office - High Rise - CAV econ | 2279 | OpenStudio |
| Office - High Rise - CAV no econ | 5303 | OpenStudio |
| Office - High Rise - FCU | 1648 | OpenStudio |
| Office - Low Rise | 6345 | OpenStudio |
| Office - Mid Rise | 3440 | OpenStudio |
| Religious Building | 7380 | eQuest |
| Restaurant | 7302 | OpenStudio |
| Retail - Department Store | 7155 | OpenStudio |
| Retail - Strip Mall | 6921 | OpenStudio |
| Warehouse | 6832 | OpenStudio |
| Unknown | 6241 | n/a |

ESF = Energy Savings Factor, the ESF for notched v-belt Installation is assumed to be 2%

= the ESF for notched Synchronous Belt Installation is assumed to be 3.1%[[56]](#footnote-56)

###### Summer Coincident Peak Demand Savings

**For example**, a notched v-belt installation in an low rise office building RTU with a 5 HP NEMA premium efficiency motor using the default hours of operation, motor load and 89.5% motor efficiency;

ΔkWh = kWconnected\* Hours \* ESF

 = ((HP \* 0.746 kW/HP\* Load Factor)/Motor Efficiency) \* Hours \* ESF

 = ((5 HP \* 0.746 kW/HP\* 80%) / 89.5%) \* 6288 \* 2%

 = 419 kWh Savings

ΔkW = kWconnected\* ESF \* CF

Where:

kWConnected = kW of equipment is calculated using motor efficiency.

= (HP \*0 .746 kW/HP\* Load Factor)/Motor Efficiency

CFSSP = Summer System Peak Coincidence Factor for Commercial cooling (during system peak hour)

= 91.3% [[57]](#footnote-57)

CFPJM = PJM Summer Peak Coincidence Factor for Commercial cooling (average during peak period)

= 47.8%[[58]](#footnote-58)

Variables as provided above

**For example**, an office building RTU with a 5 HP NEMA premium efficiency motor using the default motor load and 89.5% motor efficiency;

ΔkW = kWconnected\* ESF

 = ((HP \* 0.746 kW/HP\* Load Factor)/Motor Efficiency) \* ESF

 = ((5 HP \* 0.746 kW/HP\* 80%) / 89.5%) \* 2%

 = 0.0667 kW Savings

###### Natural Gas Savings

N/A

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: CI-HVC-NVBE-V06-210101

###### Review Deadline: 1/1/2022

### 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.[[59]](#footnote-59)

###### Deemed Measure Cost

For time of sale or new construction the incremental cost of an advanced Tier 1 power strip over a standard power strip with surge protection is assumed to be $10.[[60]](#footnote-60)

For direct install the actual full equipment and installation cost (including labor) and for kits the actual 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%.[[61]](#footnote-61)

Algorithm

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = kWh \* ISR

Where:

 kWh = Assumed annual kWh savings per unit

 = 56.5 kWh for 5-plug units or 103 kWh for 7-plug units[[62]](#footnote-62)

 ISR = In Service Rate, dependent on delivery mechanism

| **Delivery Mechanism** | **ISR** |
| --- | --- |
| Multifamily Energy Efficiency Kit, Leave behind | 40%[[63]](#footnote-63) |
| Single Family Energy Efficiency Kit, Leave behind | 55%[[64]](#footnote-64) |
| Community Distributed Kit | 91%[[65]](#footnote-65) |
| Direct Install | 100% |
| Time of Sale | 71%[[66]](#footnote-66) |

Using assumptions above:

| **# Plugs** | **Delivery Mechanism** | **ΔkWh** |
| --- | --- | --- |
| 5- plug | Multifamily Energy Efficiency Kit, Leave behind | 22.6 |
| Single family Energy Efficiency Kit, Leave behind | 31.1 |
| Community Distributed Kit | 51.4 |
| Direct Install | 56.5 |
| Time of Sale | 40.1 |
| 7-plug | Multifamily Energy Efficiency Kit, Leave behind | 41.2 |
| Single family Energy Efficiency Kit, Leave behind | 56.7 |
| Community Distributed Kit | 93.8 |
| Direct Install | 103.0 |
| Time of Sale | 73.1 |
| Unknown[[67]](#footnote-67) | Multifamily Energy Efficiency Kit, Leave behind | 31.9 |
| Single family Energy Efficiency Kit, Leave behind | 43.9 |
| Community Distributed Kit | 72.6 |
| Direct Install | 80.0 |
| Time of Sale | 56.6 |

###### Summer Coincident Peak Demand Savings

 ∆kW**=** ∆kWh/ Hours \* CF

Where:

Hours = Annual number of hours during which the controlled standby loads are turned off by the Tier 1 Advanced power Strip.

 = 7,129 [[68]](#footnote-68)

CF = Summer Peak Coincidence Factor for measure

 = 0.8 [[69]](#footnote-69)

| **# Plugs** | **Delivery Mechanism** | **ΔkW** |
| --- | --- | --- |
| 5- plug | Multifamily Energy Efficiency Kit, Leave behind | 0.0025 |
| Single family Energy Efficiency Kit, Leave behind | 0.0035 |
| Community Distributed Kit | 0.0058 |
| Direct Install | 0.0063 |
| Time of Sale | 0.0045 |
| 7-plug | Multifamily Energy Efficiency Kit, Leave behind | 0.0046 |
| Single family Energy Efficiency Kit, Leave behind | 0.0064 |
| Community Distributed Kit | 0.0105 |
| Direct Install | 0.0116 |
| Time of Sale | 0.0082 |
| Unknown[[70]](#footnote-70) | Multifamily Energy Efficiency Kit, Leave behind | 0.0036 |
| Single family Energy Efficiency Kit, Leave behind | 0.0049 |
| Community Distributed Kit | 0.0081 |
| Direct Install | 0.0090 |
| Time of Sale | 0.0064 |

###### 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-V07-210101

###### Review Deadline: 1/1/2024

### 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.[[71]](#footnote-71) 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 this is an active area of ongoing work 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.[[72]](#footnote-72) Since energy savings are applicable at the household level, savings should only be claimed for one thermostat of any type (i.e., one programmable thermostat or one advanced thermostat), and installation of multiple 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 regard to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[[73]](#footnote-73) 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,[[74]](#footnote-74) or an assumed mix of these two 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, 51% programmed programmable and 49% manual or non-programmed programmable thermostats may be assumed.[[75]](#footnote-75)

###### Deemed Lifetime of Efficient Equipment

The expected measure life for advanced thermostats is assumed to be 11 years.[[76]](#footnote-76)

###### 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,[[77]](#footnote-77) or other program types, actual costs are still preferable,[[78]](#footnote-78) but if unknown then the average incremental cost for the new installation measure is assumed to be $125.[[79]](#footnote-79)

###### Loadshape

ΔkWh 🡪 Loadshape R10 - Residential Electric Heating and Cooling

ΔkWhheating 🡪 Loadshape R09 - Residential Electric Space Heat

ΔkWhcooling 🡪 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.

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

 = 34%[[80]](#footnote-80)

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

= 23.3%[[81]](#footnote-81)

Algorithm

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh[[82]](#footnote-82) = ΔkWhheating + ΔkWhcooling

ΔkWhheating = %ElectricHeat \* Elec\_Heating\_Consumption \* Heating\_Reduction \* HF \* Eff\_ISR\_Heat + (∆Therms \* Fe \* 29.3)

ΔkWhcool = %AC \* ((FLH \* Capacity \* 1/SEER)/1000) \* Cooling\_Reduction \* Eff\_ISR\_Cool

Where:

%ElectricHeat = Percentage of heating savings assumed to be electric

|  |  |
| --- | --- |
| **Heating fuel** | **%ElectricHeat** |
| Electric | 100% |
| Natural Gas | 0% |
| Unknown | 3%[[83]](#footnote-83) |

 Elec\_Heating\_Consumption

= Estimate of annual household heating consumption for electrically heated homes.[[84]](#footnote-84) If location and heating type is unknown, assume 15,683 kWh.[[85]](#footnote-85)

| **Climate Zone****(City based upon)** | **Electric Resistance****Elec\_Heating\_ Consumption****(kWh)** | **Electric Heat Pump****Elec\_Heating\_ Consumption****(kWh)** |
| --- | --- | --- |
| 1 (Rockford) | 21,748 | 12,793 |
| 2 (Chicago) | 20,778 | 12,222 |
| 3 (Springfield) | 17,794 | 10,467 |
| 4 (Belleville) | 13,726 | 8,074 |
| 5 (Marion) | 13,970 | 8,218 |
| Average | 19,749 | 11,617 |

Heating\_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat including accounting for Thermostat Optimization services[[86]](#footnote-86)

| **Existing Thermostat Type** | **Heating\_Reduction[[87]](#footnote-87)** |
| --- | --- |
| Manual | 10.2% |
| Programmable | 7.1% |
| Unknown (Blended) | 8.5% |

HF = Household factor, to adjust heating consumption for non-single-family households.

|  |  |
| --- | --- |
| **Household Type** | **HF** |
| Single-Family | 100% |
| Mobile home | 83%[[88]](#footnote-88) |
| Multifamily | 65%[[89]](#footnote-89) |
| Actual | Custom[[90]](#footnote-90) |
| Unknown | 96.5%[[91]](#footnote-91) |

Use Multifamily if: Building has shared HVAC or meets utility’s definition for multifamily

Eff\_ISR\_Heat = Effective In-Service Rate for heating, 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.

| **Program Delivery** | **Eff\_ISR\_Heat** |
| --- | --- |
| Direct Install | 100% |
| Other programs  | 100%[[92]](#footnote-92) |

∆Therms = 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%[[93]](#footnote-94)

29.3 = kWh per therm

%AC = Fraction of customers with thermostat-controlled air-conditioning

| **Thermostat control of air conditioning?** | **%AC**[[94]](#footnote-95) |
| --- | --- |
| Yes | 100% |
| No | 0% |
| Unknown (AC-targeted program) | 99% |
| Unknown (general program) | 82.5% |

FLH = Estimate of annual household full load cooling hours for air conditioning equipment based on location and home type. If climate zone is unknown, assume the weighted average for the relevant home type. If both climate zone and home type are unknown, assume 623 hours.[[95]](#footnote-96)

| **Climate zone****(city based upon)** | **FLH****(single family)** [[96]](#footnote-97) | **FLH****(general multifamily)** [[97]](#footnote-98) | **FLH\_cooling (weatherized multifamily)** [[98]](#footnote-99) |
| --- | --- | --- | --- |
| 1 (Rockford) | 512 | 467 | 243 |
| 2 (Chicago) | 570 | 506 | 263 |
| 3 (Springfield) | 730 | 663 | 345 |
| 4 (Belleville) | 1035 | 940 | 489 |
| 5 (Marion) | 903 | 820 | 426 |
| Weighted average[[99]](#footnote-100) | 629 | 564 | 293 |

Use Multifamily if: Building has shared HVAC or meets utility’s definition for multifamily

Capacity = Size of AC unit.[[100]](#footnote-101) (Note: One refrigeration ton is equal to 12,000 Btu/hr)

 = Use actual when program delivery allows size of AC unit to be known. If unknown assume 33,600 Btu/hr for single family homes, 28,000 Btu/hr for multifamily or 24,000 Btu/hr for mobile homes.[[101]](#footnote-102) If building type is unknown, assume 33,040 Btu/hr.[[102]](#footnote-103)

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.

| **Cooling System** | **SEER[[103]](#footnote-104)** |
| --- | --- |
| Air Source Heat Pump | 12 |
| Central AC |

1/1000 = kBtu per Btu

Cooling\_Reduction = Assumed average percentage reduction in total household cooling energy consumption due to installation of advanced thermostat including accounting for Thermostat Optimization:[[104]](#footnote-105)

 = 8.4% [[105]](#footnote-106)

Eff\_ISR\_Cool = Effective In-Service Rate for cooling, 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.

|  |  |
| --- | --- |
| **Program Delivery** | **Eff\_ISR\_Cool** |
| Direct Install | 100% |
| Other programs where not evaluated | 90%[[106]](#footnote-107) |

**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:

ΔkWH = ΔkWhheating + ΔkWhcooling

= 1 \* 10,464 \* 7.1% \* 100% \* 100% + (0 \* 0.0314 \* 29.3) + 100% \* ((730 \* 33,600 \* (1/12))/1000) \* 8.4% \* 100%

= 743kWh + 172 kWh

= 915 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = %AC \* (Cooling\_DemandReduction \* Btu/hr \* (1/EER)/1000) \* EFF\_ISR\_Cool \* CF

Where:

Cooling\_DemandReduction = Assumed average percentage reduction in total household cooling demand due to installation of advanced thermostat including accounting for Thermostat Optimization services

 = 16.4%[[107]](#footnote-108)

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

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

EER = (-0.02 \* SEER\_exist2) + (1.12 \* SEER\_exist) [[108]](#footnote-109)

If SEER or EER rating unavailable use:

| **Cooling System** | **EER[[109]](#footnote-110)** |
| --- | --- |
| Air Source Heat Pump | 10.5 |
| Central AC |

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

 = 34%[[110]](#footnote-111)

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

 = 23.3%[[111]](#footnote-112)

**For example**, an advanced thermostat replacing a programmable thermostat directly installed in an electric resistance heated, single-family home in Springfield with advanced thermostat-controlled air conditioning of a system of unknown size and seasonal efficiency rating:

ΔkW SSP = 100% \* (16.4% \* 33,600 \* (1/10.5)/1000) \* 100% \* 34%

= 0.1784 kW

ΔkW PJM = 100% \* (16.4% \* 33,600 \* (1/10.5)/1000) \* 100% \* 23.3%

= 0.1223 kW

###### Natural Gas Energy Savings

∆Therms = %FossilHeat \* Gas\_Heating\_Consumption \* Heating\_Reduction \* HF \* Eff\_ISR\_Heat

Where:

%FossilHeat = Percentage of heating savings assumed to be Natural Gas

|  |  |
| --- | --- |
| **Heating fuel** | **%FossilHeat** |
| Electric | 0% |
| Natural Gas | 100% |
| Unknown | 97%[[112]](#footnote-113) |

Gas\_Heating\_Consumption

= Estimate of annual household heating consumption for gas heated single-family homes. If location is unknown, assume the average below.[[113]](#footnote-114)

| **Climate Zone****(City based upon)** | **Gas\_Heating\_ Consumption****(therms)** |
| --- | --- |
| 1 (Rockford) | 1,052 |
| 2 (Chicago) | 1,005 |
| 3 (Springfield) | 861 |
| 4 (Belleville) | 664 |
| 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:

∆Therms = 1.0 \* 1005 \* 7.1% \* 100% \* 100%

 = 71.4 therms

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: RS-HVC-ADTH-V06-210101

###### Review Deadline: 1/1/2022

### 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 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 97% Residential and 3% Commercial assumptions should be used.[[114]](#footnote-115)

This measure was developed to be applicable to the following program types:  TOS, NC, EREP, 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, new lamps must be ENERGY STAR labeled. Note a new ENERGY STAR specification v2.1 became effective on 1/2/2017.

###### Definition of Baseline Equipment

In 2012, Federal legislation stemming from the Energy Independence and Security Act of 2007 (EISA) 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.

Additionally, an EISA backstop provision was included that would require replacement baseline lamps to meet an efficacy requirement of 45 lumens/watt or higher beginning on 1/1/2020. However, in December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that this more stringent standard was not economically justified.

The natural growth of LED market share however, has and will continue to grow over the lifetime of the LED measures installed. The TAC convened a Lamp Forecast Working Group to develop a forecast of the baseline growth of LED, based upon historical growth rates provided via CREED LightTracker data, comparisons of with and no-program states and review of projections provided by the Department of Energy.[[115]](#footnote-116)

This baseline forecast was then used to estimate how replacement lamps would change over the lifetime of an LED. A single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings.

Income Eligible Program Adjustments

The Lamp Forecast Working Group also developed forecasts for estimated Income Eligible market growth in LEDs. These forecasts are used to provide a separate mid-life adjustment for programs supporting income eligible populations. Note that upstream lighting programs in DIY, Warehouse, and Big Box stores located in income eligible neighborhoods should not assume that all customers are from income eligible populations, as data has indicated that the product selection and low prices found in these stores attract customers from beyond.[[116]](#footnote-117) A weighted blend of the two measure types (Income eligible and non-income eligible) can be used for DIY, Warehouse, and Big Box stores located in income eligible neighborhoods based upon primary evaluation research at these store types, or using a default of 30% income eligible customers.[[117]](#footnote-118)

New Construction Programs

Since IECC 2015 energy code, there has been mandatory requirements for lighting in New Construction: *“Not less than 75 percent (90 percent in IECC 2018) of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 75 percent (90 percent in IECC 2018) of the permanently installed lighting fixtures shall contain only high-efficacy lamps”*. To meet the ‘high efficacy’ requirements, lamps need to be CFL or LED, however since CFLs are no longer commonly purchased (only 1% baseline forecast) it is assumed that 75% (IECC 2015) or 90% (IECC 2018) of the New Construction baseline is an LED and therefore savings are reduced by that percentage for bulbs provided in New Construction projects.

Early Replacement

The baseline for the early replacement measure is the existing bulb being replaced.

###### Deemed Lifetime of Efficient Equipment

The average rated life for Omnidirectional lamps on the ENERGY STAR Qualified Products list (accessed 6/16/2020) is approximately 20,000 hours.

The deemed measure life is 8 years for exterior application and lifetimes are capped at 10 years for other applications.[[118]](#footnote-119)

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.[[119]](#footnote-120)

###### 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:[[120]](#footnote-121)

| **Year** | **EISA Compliant Halogen** | **LED A-Lamp** | **Incremental Cost** | **Incremental Cost for New Construction** |
| --- | --- | --- | --- | --- |
| **(IECC 2015)** | **(IECC 2018)** |
| 2020 and on | $1.25 | $2.70 | $1.45 | $0.36 | $0.15  |

###### Loadshape

|  |
| --- |
| Loadshape R06 – Residential Indoor Lighting |
| Loadshape R07 – Residential Outdoor Lighting |

###### Coincidence Factor

The summer peak coincidence factor is assumed to be 0.128 for Residential and in-unit Multi Family bulbs,[[121]](#footnote-122) 0.273 for exterior bulbs,[[122]](#footnote-123) and 0.135 for unknown,[[123]](#footnote-124)

Use Multifamily if: Building meets utility’s definition for multifamily.

**Algorithm**

###### Calculation of Savings

###### Electric Energy Savings

ΔkWh = ((Wattsbase-WattsEE)/1000) \* ISR \* (1-Leakage) \* Hours \*WHFe

Where:

Wattsbase = Input wattage of the existing or baseline system. Reference the “LED New and Baseline Assumptions” table for default values.

WattsEE = Actual wattage of LED purchased / installed. If unknown, use default provided below:[[124]](#footnote-125)

 **LED New and Baseline Assumptions Table**

| **Minimum Lumens** | **Maximum Lumens** | **Lumens used to calculate LED Wattage****(midpoint)** | **LED Wattage [[125]](#footnote-126)(WattsEE)** | **Baseline (WattsBase)** | **Baseline for New Construction****(WattsBase)** | **Delta Watts (WattsEE)** | **Delta Watts for New Construction(WattsEE)** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **(IECC 2015)** | **(IECC 2018)** | **(IECC 2015)** | **(IECC 2018)** |
| 5280 | 6209 | 5745 | 72.9 | 300.0 | 129.7 | 95.6 | 227.1 | 56.8 | 22.7 |
| 3301 | 5279 | 4290 | 54.5 | 200.0 | 90.9 | 69.1 | 145.5 | 36.4 | 14.6 |
| 2601 | 3300 | 2951 | 37.5 | 150.0 | 65.6 | 48.8 | 112.5 | 28.1 | 11.3 |
| 1490 | 2600 | 2045 | 26.0 | 72.0 | 37.5 | 30.6 | 46.0 | 11.5 | 4.6 |
| 1050 | 1489 | 1270 | 16.1 | 53.0 | 25.3 | 19.8 | 36.9 | 9.2 | 3.7 |
| 750 | 1049 | 900 | 11.4 | 43.0 | 19.3 | 14.6 | 31.6 | 7.9 | 3.2 |
| 310 | 749 | 530 | 6.7 | 29.0 | 12.3 | 8.9 | 22.3 | 5.6 | 2.2 |
| 250 | 309 | 280 | 3.5 | 25.0 | 8.9 | 5.7 | 21.5 | 5.4 | 2.2 |

ISR = In Service Rate, the percentage of lamps rebated that are actually in service.

| **Program** | **Weighted Average 1st year In Service Rate (ISR)** | **2nd year Installations** | **3rd year Installations** | **Final Lifetime In Service Rate[[126]](#footnote-127)** |
| --- | --- | --- | --- | --- |
| Retail (Time of Sale)  | 76.0%[[127]](#footnote-128) | 11.9% | 10.1% | 98.0%[[128]](#footnote-129) |
| Direct Install | 94.5%[[129]](#footnote-130) |  |  |  |
| Efficiency Kits[[130]](#footnote-131) | LED Distribution[[131]](#footnote-132) | 59% | 13% | 11% | 83% |
| School Kits[[132]](#footnote-133) | 60% | 13% | 11% | 84% |
| Direct Mail Kits[[133]](#footnote-134) | 66% | 14% | 12% | 93% |
| Direct Mail Kits, Income Qualified[[134]](#footnote-135) | 68% | 15% | 12% | 95% |
| Community Distributed Kits[[135]](#footnote-136) | 88% | 4% | 3% | 95% |
| Food Bank / Pantry Distribution[[136]](#footnote-137) | 80.3%[[137]](#footnote-138) | 9.6% | 8.1% | 98%[[138]](#footnote-139) |

Leakage = Adjustment to account for the percentage of program bulbs that move out (and in if deemed appropriate)[[139]](#footnote-140) of the Utility Jurisdiction.

KITS programs = Determined through evaluation

Upstream (TOS) Lighting programs = Use deemed assumptions below:[[140]](#footnote-141)

 ComEd: 0.8%

 Ameren: 13.1%

All other programs = 0

Hours = Average hours of use per year

| **Installation Location** | **Hours** |
| --- | --- |
| Residential and in-unit Multi Family | 1,089[[141]](#footnote-142)  |
| Exterior | 2,475[[142]](#footnote-143)  |
| Unknown | 1,159[[143]](#footnote-144) |

WHFe = Waste heat factor for energy to account for cooling energy savings from efficient lighting

| **Bulb Location** | **WHFe** |
| --- | --- |
| Interior single family  | 1.06 [[144]](#footnote-145) |
| Multifamily in unit | 1.04 [[145]](#footnote-146) |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.051[[146]](#footnote-147) |

**For example**, an 8W LED lamp, 450 lumens, is installed in the interior of a home. The customer purchased the lamp through a ComEd upstream program:

ΔkWh = ((29.0 - 6.7) /1000) \* 0.784 \* (1 - 0.008) \* 1,089 \* 1.06

= 20.0 kWh

**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 2 and 3 installs: Characterized using delta watts assumption and hours of use from the Install Year; i.e., the actual deemed assumptions active in Year 2 and 3 should be applied.

The NTG factor for the Purchase Year should be applied.

**For example:** using the assumptions from above, for an 8W LED, 450 Lumens purchased for the interior of a residential homes through a ComEd upstream program.

ΔkWh2nd year installs = ((29 - 6.7)/1000) \* 0.106 \* (1 – 0.008) \* 1,089 \* 1.06

= 2.7 kWh

ΔkWh3rd year installs = ((29 - 6.7)/1000) \* 0.09 \* (1 – 0.008) \* 1,089 \* 1.06

= 2.3 kWh

Note: Here we assume no change in hours assumption. NTG value from Purchase year should be applied.

**Heating Penalty**

If electric heated home (if heating fuel is unknown assume gas, see Natural Gas section):

∆kWh[[147]](#footnote-148) = - (((WattsBase - WattsEE) / 1000) \* ISR \* (1-Leakage) \* Hours \* HF) / ηHeat

Where:

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

 = 49% for interior[[148]](#footnote-149)

 = 0% for exterior or unheated location

= 42% for unknown location[[149]](#footnote-150)

ηHeat = Efficiency in COP of Heating equipment

= actual. If not available use:[[150]](#footnote-151)

|  |  |  |  |
| --- | --- | --- | --- |
| **System Type** | **Age of Equipment** | **HSPF Estimate** | **COPHEAT****(COP Estimate)****= (HSPF/3.413)\*0.85** |
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| After 2006 - 2014 | 7.7 | 1.92 |
| 2015 on  | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1.00 |
| Unknown[[151]](#footnote-152) | N/A | N/A | 1.28 |

**For example**: using the same 8 W LED that is installed in home with 2.0 COP Heat Pump (including duct loss) through a ComEd upstream program:

∆kWh1st year = - (((29 - 6.7) / 1000) \* 0.784 \* (1-0.008) \* 1,089 \* 0.42) / 2.0

 = - 4.0 kWh

Second and third year install savings should be calculated using the appropriate ISR and the delta watts and hours from the install year.

**Mid-Life Baseline Adjustment**

During the lifetime of a standard Omnidirectional LED, the baseline incandescent/halogen bulb would need to be replaced multiple times. In December 2019, DOE issued a final determination for General Service Incandescent Lamps (GSILs), finding that the more stringent standards (45 lumen per watt) prescribed in the 2007 EISA regulation to become effective in 2020 (known as the ‘Backstop’ provision), was not economically justified. However, natural growth of LED market share has, and will continue to grow over the lifetime of the measure, and so a single mid-life adjustment is calculated that results in an equivalent net present value of lifetime savings as the forecast decline in annual savings. See ‘Lamp Forecast Workbook\_2020.xls’ for details.

The calculated mid-life adjustments for 2021 are provided below for each population:

| **Population** | **Year from which adjustment is applied** | **Adjustment Factor applied to Annual kWh Savings** |
| --- | --- | --- |
| Income Eligible | 2028 | 79% |
| All others | 2025 | 38% |

**For example**, an 8W LED lamp, 450 lumens, is installed in the interior of a home. The customer purchased the lamp through a ComEd upstream program:

ΔkWh (2021-2024) = ((29.0 - 6.7) /1000) \* 0.784 \* (1 - 0.008) \* 1,089 \* 1.06

= 20.0 kWh

ΔkWh (2025 on) = 20.0 \* 0.38

= 7.6 kWh

**Summer Coincident Peak Demand Savings**

∆kW = ((WattsBase - WattsEE) / 1000) \* ISR \* (1-Leakage) \* WHFd \* CF

Where:

WHFd = Waste heat factor for demand to account for cooling savings from efficient lighting.

| **Bulb Location** | **WHFd** |
| --- | --- |
| Interior single family  | 1.11[[152]](#footnote-153) |
| Multifamily in unit | 1.07[[153]](#footnote-154) |
| Exterior or uncooled location | 1.0 |
| Unknown location | 1.093[[154]](#footnote-155) |

CF = Summer Peak Coincidence Factor for measure.

| **Bulb Location** | **CF** |
| --- | --- |
| Interior  | 0.128[[155]](#footnote-156)  |
| Exterior | 0.273[[156]](#footnote-157) |
| Unknown | 0.135[[157]](#footnote-158) |

Other factors as defined above

**For example:** for the same 8 W LED that is installed in a single family interior location through a ComEd upstream program:

ΔkW = ((29 - 6.7) / 1000) \* 0.784 \* (1-0.008) \* 1.11 \* 0.128

= 0.0025 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**

Heating penalty if Natural Gas heated home, or if heating fuel is unknown.

ΔTherms = - (((WattsBase - WattsEE) / 1000) \* ISR \* (1-Leakage) \* Hours \* HF \* 0.03412) / ηHeat

Where:

HF = Heating factor, or percentage of lighting savings that must be replaced by heating system.

= 49% for interior[[158]](#footnote-159)

= 0% for exterior location

= 42% for unknown location[[159]](#footnote-160)

0.03412 = Converts kWh to Therms

ηHeat = Average heating system efficiency.

 = 0.70 [[160]](#footnote-161)

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

In order to account for the natural growth of LED over the lifetime of the measure, an equivalent annual levelized baseline replacement cost is calculated and applied over the life of the measure as described above.

The NPV for replacement lamps and annual levelized replacement costs using the societal real discount rate of 0.42% are presented below.[[161]](#footnote-162) 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:

| **Population** | **Location** | **NPV of replacement costs for period** | **Levelized annual replacement cost savings** |
| --- | --- | --- | --- |
| **2021** | **2021** |
| Income eligible | Residential and in-unit Multi Family, and Unknown | $9.97  | $1.02  |
| Exterior | $16.66  | $2.12  |
| All others | Residential and in-unit Multi Family, and Unknown | $7.83  | $0.80  |
| Exterior | $9.97  | $1.02  |

**Measure Code: RS-LTG-LEDA-V11-210101**

###### Review Deadline: 1/1/2022

### 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 multifamily 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 20 years.[[162]](#footnote-163)

The expected measure life of prescriptive shrink-fit window film is assumed to be 1 year.

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[[163]](#footnote-164) See section below for detail.

###### 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 capacity market.

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

= 68%[[164]](#footnote-165)

CFSSP = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

 = 72%%[[165]](#footnote-166)

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

= 46.6%[[166]](#footnote-167)

Algorithm

###### Calculation of Savings

###### Electric Energy Savings

Preferred methodology unless blower door testing is not possible.

ΔkWh = ΔkWh\_cooling + ΔkWh\_heatingElectric + ΔkWh\_heatingGas

Where:

ΔkWh\_cooling = If central cooling, reduction in annual cooling requirement due to air sealing

= [(((CFM50\_existing - CFM50\_new)/N\_cool) \* 60 \* 24 \* CDD \* DUA \* 0.018) / (1000 \* ηCool) \* LM \* ADJAirSealingCool] \* IENetCorrection \* %Cool

CFM50\_existing = Infiltration at 50 Pascals as measured by blower door before air sealing.

 = Actual

CFM50\_new = Infiltration at 50 Pascals as measured by blower door after air sealing.

 = Actual

N\_cool = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

 =Dependent on location and number of stories:[[167]](#footnote-168)

| **Climate Zone****(City based upon)** | **N\_cool (by # of stories)** |
| --- | --- |
| **1** | **1.5** | **2** | **3** |
| 1 (Rockford) | 39.5 | 35.0 | 32.1 | 28.4 |
| 2 (Chicago) | 38.9 | 34.4 | 31.6 | 28.0 |
| 3 (Springfield) | 41.2 | 36.5 | 33.4 | 29.6 |
| 4 (St Louis, MO) | 40.4 | 35.8 | 32.9 | 29.1 |
| 5 (Paducah, KY) | 43.6 | 38.6 | 35.4 | 31.3 |

60 \* 24 = Converts Cubic Feet per Minute to Cubic Feet per Day

CDD = Cooling Degree Days

 = Dependent on location:[[168]](#footnote-169)

|  |  |
| --- | --- |
| **Climate Zone (City based upon)** | **CDD 65** |
| 1 (Rockford) | 820 |
| 2 (Chicago) | 842 |
| 3 (Springfield) | 1,108 |
| 4 (Belleville) | 1,570 |
| 5 (Marion) | 1,370 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [[169]](#footnote-170)

0.018 = Specific Heat Capacity of Air (Btu/ft3\*°F)

1000 = Converts Btu to kBtu

 ηCool = Efficiency (SEER) of Air Conditioning equipment (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following:[[170]](#footnote-171)

| **Age of Equipment** | **SEER Estimate** |
| --- | --- |
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |
| Unknown (for use in program evaluation only) | 10.5 |

LM = Latent multiplier to account for latent cooling demand[[171]](#footnote-172)

| **Climate Zone****(City based upon)** | **LM** |
| --- | --- |
| 1 (Rockford) | 3.3 |
| 2 (Chicago) | 3.2 |
| 3 (Springfield) | 3.7 |
| 4 (St Louis, MO) | 3.6 |
| 5 (Paducah, KY) | 3.7 |

ADJAirSealingCool = Adjustment for cooling savings to account for innacuracies in engineering algorithms[[172]](#footnote-173)

| **Measure** | **ADJAirSealingCool** |
| --- | --- |
| Air sealing and attic insulation | 121% |
| Air sealing without attic insulation | 100% |

IENetCorrection = 100% if not income eligible or air sealing is installed without attic insulation.

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using ADJAirSealingCool of 121% [[173]](#footnote-174)

%Cool = Percent of homes that have cooling

| **Central Cooling?** | **%Cool** |
| --- | --- |
| Yes | 100% |
| No | 0% |
| Unknown (for use in program evaluation only)[[174]](#footnote-175) | 66% |

ΔkWh\_heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to air sealing

= [(((CFM50\_existing - CFM50\_new)/N\_heat) \* 60 \* 24 \* HDD \* 0.018) / (ηHeat \* 3,412)] \*%ElectricHeat

N\_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

 = Based on climate zone, building height and exposure level:[[175]](#footnote-176)

| **Climate Zone****(City based upon)** | **N\_heat (by # of stories)** |
| --- | --- |
| **1** | **1.5** | **2** | **3** |
| 1 (Rockford) | 23.8 | 21.1 | 19.3 | 17.1 |
| 2 (Chicago) | 23.9 | 21.1 | 19.4 | 17.2 |
| 3 (Springfield) | 24.2 | 21.5 | 19.7 | 17.4 |
| 4 (St Louis, MO) | 25.4 | 22.5 | 20.7 | 18.3 |
| 5 (Paducah, KY) | 27.8 | 24.6 | 22.6 | 20.0 |

 HDD = Heating Degree Days

 = Dependent on location:[[176]](#footnote-177)

| **Climate Zone****(City based upon)** | **HDD 60** |
| --- | --- |
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below:[[177]](#footnote-178)

|  |  |  |  |
| --- | --- | --- | --- |
| **System Type** | **Age of Equipment** | **HSPF Estimate** | **ηHeat (Effective COP Estimate)= (HSPF/3.413)\*0.85** |
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| 2006 - 2014 | 7.7 | 1.92 |
| 2015 on  | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |
| Unknown (for use in program evaluation only)[[178]](#footnote-179) | N/A | N/A | 1.28 |

3412 = Converts Btu to kWh

%ElectricHeat = Percent of homes that have electric space heating

| **Heating System** | **%ElectricHeat** |
| --- | --- |
| Electric resistance or heat pump | 100% |
| Natural Gas  | 0% |
| Unknown heating fuel (for use in program evaluation only)[[179]](#footnote-180) | 13% |

**For example:** energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

Assume a 2 story single family non-income eligible home in Chicago completes air sealing, installs attic insulation, has 10.5 SEER central cooling and a heat pump with COP of 2 (1.92 including distribution losses), and has pre and post blower door test results of 3,400 and 2,250:

ΔkWh = ΔkWh\_cooling + ΔkWh\_heating

= [(((3,400 – 2,250) / 31.6) \* 60 \* 24 \* 842 \* 0.75 \* 0.018) / (1000 \* 10.5) \* 3.2 \* 121%] \* 100% \* 100% + [(((3,400 – 2,250) / 19.4) \* 60 \* 24 \* 5113 \* 0.018) / (1.92 \* 3,412)] \* 100%

= 220 + 1,199

= 1,419 kWh

ΔkWh\_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

 = ΔTherms \* Fe \* 29.3 \* ADJAirSealingHeatFan

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

 = 3.14%[[180]](#footnote-181)

29.3 = kWh per therm

ADJAirSealingHeatFan = Adjustment for fan savings during heating season to account for innacuracies in engineering algorithms[[181]](#footnote-182)

| **Measure** | **ADJAirSealingHeatFan** |
| --- | --- |
| Air sealing and attic insulation | 107% |
| Air sealing without attic insulation | 100% |

**For example:** energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

Assume a well shielded, 2 story non-income eligible single family home in Chicago completes air sealing, installs attic insulation, has a gas furnace with system efficiency of 70%, and has pre and post blower door test results of 3,400 and 2,250 (see therm calculation in Natural Gas Savings section):

ΔkWh\_heatingGas = 76.3 \* 0.0314 \* 29.3 \* 107%

= 75.1 kWh

***Methodology 2: Prescriptive Infiltration Reduction Measures[[182]](#footnote-184)***

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible. Cooling savings are not quantified using Methodology 2.

ΔkWh\_heating = (ΔkWhgasket \* ngasket + ΔkWhwindows \* sfwindows + ΔkWhsweep \* nsweep + ΔkWhsealing \* lfsealing + ΔkWhWX \* lfWX) \* ADJRxAirsealing \* ISR

Where:

ΔkWhgasket = Annual kWh savings from installation of air sealing gasket on an electric outlet

| **Climate Zone****(City based upon)** | **ΔkWhgasket / gasket** |
| --- | --- |
| **Electric Resistance** | **Heat Pump** |
| 1 (Rockford) | 10.5 | 5.3 |
| 2 (Chicago) | 10.2 | 5.1 |
| 3 (Springfield) | 8.8 | 4.4 |
| 4 (Belleville) | 7.0 | 3.5 |
| 5 (Marion) | 7.2 | 3.6 |

ngasket = Number of gaskets installed

ΔkWhwindows = Annual kWh savings from installation of Shrink-Fit Window Kit[[183]](#footnote-185)

| **Climate Zone****(City based upon)** | **ΔkWhwindows / sf****Electric Resistance** | **ΔkWhwindows / sf****Heat Pump** |
| --- | --- | --- |
| 1 (Rockford) | 4.0 | 2.1 |
| 2 (Chicago) | 3.9 | 2.0 |
| 3 (Springfield) | 3.3 | 1.7 |
| 4 (Belleville) | 2.5 | 1.3 |
| 5 (Marion) | 2.6 | 1.3 |

sfwindows = square footage of shrink-fit window film

ΔkWhsweep =Annual kWh savings from installation of door sweep

| **Climate Zone****(City based upon)** | **ΔkWhsweep / sweep** |
| --- | --- |
| **Electric Resistance** | **Heat Pump** |
| 1 (Rockford) | 202.4 | 101.2 |
| 2 (Chicago) | 195.3 | 97.6 |
| 3 (Springfield) | 169.3 | 84.7 |
| 4 (Belleville) | 134.9 | 67.5 |
| 5 (Marion) | 137.9 | 68.9 |

nsweep = Number of sweeps installed

ΔkWhsealing = Annual kWh savings from foot of caulking, sealing, or polyethlylene tape

| **Climate Zone****(City based upon)** | **ΔkWhsealing / ft** |
| --- | --- |
| **Electric Resistance** | **Heat Pump** |
| 1 (Rockford) | 11.6 | 5.8 |
| 2 (Chicago) | 11.2 | 5.6 |
| 3 (Springfield) | 9.7 | 4.8 |
| 4 (Belleville) | 7.7 | 3.9 |
| 5 (Marion) | 7.9 | 3.9 |

lfsealing = linear feet of caulking, sealing, or polyethylene tape

ΔkWhWX = Annual kWh savings from window weatherstripping or door weatherstripping

| **Climate Zone****(City based upon)** | **ΔkWhWX / ft** |
| --- | --- |
| **Electric Resistance** | **Heat Pump** |
| 1 (Rockford) | 13.5 | 6.7 |
| 2 (Chicago) | 13.0 | 6.5 |
| 3 (Springfield) | 11.3 | 5.6 |
| 4 (Belleville) | 9.0 | 4.5 |
| 5 (Marion) | 9.2 | 4.6 |

lfWX = Linear feet of window weatherstripping or door weatherstripping

ADJRxAirsealing = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[[184]](#footnote-186)

 = 80%

ISR = In service rate of weatherization kits dependant on install method as listed in table below.

| **Selection** | **ISR** |
| --- | --- |
| Distributed School Weatherization Kits | 0.58[[185]](#footnote-187) |
| Other Weatherization Kits  | 0.87[[186]](#footnote-188) |
| Direct Install, Retail | 1.0 |

###### Summer Coincident Peak Demand Savings

ΔkW = (ΔkWh\_cooling / FLH\_cooling) \* CF

Where:

FLH\_cooling = Full load hours of air conditioning

 = Dependent on location:[[187]](#footnote-189)

| **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 |

Use Multifamily if: Building has shared HVAC or meets utility’s definition for multifamily

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

 = 68%[[188]](#footnote-190)

CFSSP = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

 = 72%% [[189]](#footnote-191)

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

= 46.6% [[190]](#footnote-192)

 Other factors as defined above.

**For example:** energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

Assume a well shielded, 2 story non-income eligible single family home in Chicago completes air sealing, installs attic insulation, has 10.5 SEER central cooling and a heat pump with COP of 2.0, and has pre and post blower door test results of 3,400 and 2,250:

ΔkWSSP = 220 / 570 \* 0.68

= 0.26 kW

ΔkWPJM = 220 / 570 \* 0.466

= 0.18 kW

###### Natural Gas Savings

***Methodology 1: Blower Door Test***

Preferred methodology unless blower door testing is not possible.

If Natural Gas heating:

ΔTherms = (((CFM50\_existing - CFM50\_new)/N\_heat) \* 60 \* 24 \* HDD \* 0.018) / (ηHeat \* 100,000) \* ADJAirSealingGasHeat \* IENetCorrection

Where:

N\_heat = Conversion factor from leakage at 50 Pascal to leakage at natural conditions

 = Based on climate zone and building height:[[191]](#footnote-193)

| **Climate Zone****(City based upon)** | **N\_heat (by # of stories)** |
| --- | --- |
| **1** | **1.5** | **2** | **3** |
| 1 (Rockford) | 23.8 | 21.1 | 19.3 | 17.1 |
| 2 (Chicago) | 23.9 | 21.1 | 19.4 | 17.2 |
| 3 (Springfield) | 24.2 | 21.5 | 19.7 | 17.4 |
| 4 (St Louis, MO) | 25.4 | 22.5 | 20.7 | 18.3 |
| 5 (Paducah, KY) | 27.8 | 24.6 | 22.6 | 20.0 |

HDD = Heating Degree Days

 = dependent on location:[[192]](#footnote-194)

| **Climate Zone****(City based upon)** | **HDD 60** |
| --- | --- |
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |

ηHeat = Efficiency of heating system

= Equipment efficiency \* distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[[193]](#footnote-195) If not available, use 72% for existing system efficiency.[[194]](#footnote-196)

ADJAirSealingGasHeat = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms:[[195]](#footnote-197)

| **Measure** | **ADJAirSealingGasHeat** |
| --- | --- |
| Air sealing and attic insulation | 72% |
| Air sealing without attic insulation | 100% |

IENetCorrection = 100% if not income eligible or air sealing is installed without attic insulation

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using ADJAirSealingGasHeat of 72%[[196]](#footnote-198)

%GasHeat = Percent of homes that have gas space heating

| **Heating System** | **%GasHeat** |
| --- | --- |
| Electric resistance or heat pump | 0% |
| Natural Gas  | 100% |
| Unknown heating fuel (for use in program evaluation only)[[197]](#footnote-199) | 87% |

Other factors as defined above.

**For example:** energy savings from air sealing. Energy savings for attic insulation are included in a separate example in Section 5.6.5: Ceiling/Attic Insulation.

Assume a 2 story non-income eligible single family home in Chicago completes air sealing, installs attic insulation, has a gas furnace with system efficiency of 70%, and has pre and post blower door test results of 3,400 and 2,250:

ΔTherms = (((3,400 – 2,250)/19.4) \* 60 \* 24 \* 5113 \* 0.018) / (0.72 \* 100,000) \* 72% \* 100%

= 78.5 therms

***Methodology 2: Prescriptive Infiltration Reduction Measures[[198]](#footnote-200)***

Savings shall only be calculated via Methodology 2 if a blower door test is not feasible.

Δtherms = (Δthermsgasket \* ngasket + Δthermswindows \* sfwindows + Δthermssweep \* nsweep + Δthermssealing \* lfsealing + ΔthermsWX \* lfWX) \* ADJRxAirsealing \* ISR

Where:

Δthermsgasket = Annual therm savings from installation of air sealing gasket on an electric outlet

| **Climate Zone****(City based upon)** | **Δthermsgasket / gasket****Gas Heat** |
| --- | --- |
| 1 (Rockford) | 0.49 |
| 2 (Chicago) | 0.47 |
| 3 (Springfield) | 0.41 |
| 4 (Belleville) | 0.33 |
| 5 (Marion) | 0.33 |

ngasket = Number of gaskets installed

Δthermswindows = Annual therm savings from installation of Shrink-Fit Window Kit:[[199]](#footnote-201)

|  |  |
| --- | --- |
| **Climate Zone****(City based upon)** | **Δthermswindows / sf****Gas Heat** |
| 1 (Rockford) | 0.191 |
| 2 (Chicago) | 0.183 |
| 3 (Springfield) | 0.156 |
| 4 (Belleville) | 0.121 |
| 5 (Marion) | 0.123 |

sfwindows = square footage of shrink-fit window film

Δthermssweep = Annual therm savings from installation of door sweep

| **Climate Zone****(City based upon)** | **Δthermssweep / sweep****Gas Heat** |
| --- | --- |
| 1 (Rockford) | 9.46 |
| 2 (Chicago) | 9.13 |
| 3 (Springfield) | 7.92 |
| 4 (Belleville) | 6.31 |
| 5 (Marion) | 6.45 |

nsweep = Number of sweeps installed

Δthermssealing = Annual therm savings from foot of caulking, sealing, or polyethlylene tape

| **Climate Zone****(City based upon)** | **Δthermssealing / ft****Gas Heat** |
| --- | --- |
| 1 (Rockford) | 0.54 |
| 2 (Chicago) | 0.52 |
| 3 (Springfield) | 0.45 |
| 4 (Belleville) | 0.36 |
| 5 (Marion) | 0.37 |

lfsealing = linear feet of caulking, sealing, or polyethylene tape

ΔthermsWX = Annual therm savings from window weatherstripping or door weatherstripping

| **Climate Zone****(City based upon)** | **Δthermssx / ft****Gas Heat** |
| --- | --- |
| 1 (Rockford) | 0.63 |
| 2 (Chicago) | 0.61 |
| 3 (Springfield) | 0.53 |
| 4 (Belleville) | 0.42 |
| 5 (Marion) | 0.43 |

lfWX = Linear feet of window weatherstripping or door weatherstripping

ADJRxAirsealing = Adjustment for air sealing savings to account for prescriptive estimates overclaiming savings[[200]](#footnote-202)

 = 80%

ISR = In service rate of weatherization kits dependent on install method as listed in table below

| **Selection** | **ISR** |
| --- | --- |
| Distributed School Weatherization Kits | 0.58[[201]](#footnote-203) |
| Other Weatherization Kits  | 0.87[[202]](#footnote-204) |
| Direct Install, Retail | 1.0 |

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the life time of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| **Efficiency Assumption** | **System Type** | **New Baseline Efficiency** |
| --- | --- | --- |
| ηCool  | Central AC | 13 SEER |
| Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| Heat Pump(8.2HSPF/3.413)\*0.85 | 2.04 COP |
| Furnace90% AFUE \* 0.85 | 76.5% AFUE |
| Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers.[[203]](#footnote-205) Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: RS-SHL-AIRS-V10-210101

###### Review Deadline: 1/1/2024

### Ceiling/Attic Insulation

###### Description

Insulation is added to 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 little or no attic insulation.

###### Deemed Lifetime of Efficient Equipment

The expected measure life is assumed to be 20 years.[[204]](#footnote-206)

Note a mid-life adjustment to account for replacement of HVAC equipment during the measure life should be applied after 10 years or 13 years for boilers.[[205]](#footnote-207) See section below for detail.

###### 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 capacity market.

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

= 68%[[206]](#footnote-208)

CFSSP = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

 = 72%%[[207]](#footnote-209)

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

= 46.6%[[208]](#footnote-210)

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.

ΔkWh = (ΔkWh\_cooling + ΔkWh\_heatingElectric + ΔkWh\_heatingGas)

Where

ΔkWh\_cooling = If central cooling, reduction in annual cooling requirement due to celing/attic insulation

= ((((1/R\_old - 1/R\_attic) \* A\_attic \* (1-Framing\_factor\_attic)) \* 24 \* CDD \* DUA) / (1000 \* ηCool)) \* ADJAtticCool \* IENetCorrection \* %Cool

R\_attic = R-value of new attic assembly (including all layers between inside air and outside air).

R\_old = R-value value of existing assembly and any existing insulation.

(Minimum of R-3 for uninsulated assemblies)[[209]](#footnote-211)

A\_attic = Total area of insulated ceiling/attic (ft2)

Framing\_factor\_attic = Adjustment to account for area of framing

 = 7%[[210]](#footnote-212)

24 = Converts hours to days

CDD = Cooling Degree Days

 = dependent on location:[[211]](#footnote-213)

| **Climate Zone****(City based upon)** | **CDD 65** |
| --- | --- |
| 1 (Rockford) | 820 |
| 2 (Chicago) | 842 |
| 3 (Springfield) | 1,108 |
| 4 (Belleville) | 1,570 |
| 5 (Marion) | 1,370 |
| Weighted Average[[212]](#footnote-214) | 947 |

DUA = Discretionary Use Adjustment (reflects the fact that people do not always operate their AC when conditions may call for it).

= 0.75 [[213]](#footnote-215)

1000 = Converts Btu to kBtu

ηCool = Seasonal Energy Efficiency Ratio of cooling system (kBtu/kWh)

= Actual (where new or where it is possible to measure or reasonably estimate). If unknown assume the following:[[214]](#footnote-216)

| **Age of Equipment** | **SEER Estimate** |
| --- | --- |
| Before 2006 | 10 |
| 2006 - 2014 | 13 |
| Central AC After 1/1/2015 | 13 |
| Heat Pump After 1/1/2015 | 14 |
| Unknown (for use in program evaluation only) | 10.5 |

ADJAtticCool = Adjustment for cooling savings to account for inaccuracies in engineering algorithms[[215]](#footnote-217)

 = 121%

IENetCorrection = 100% if not income eligible or attic insulation is installed without air sealing

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using ADJAtticCool of 121%[[216]](#footnote-218)

%Cool = Percent of homes that have cooling

| **Central Cooling?** | **%Cool** |
| --- | --- |
| Yes | 100% |
| No | 0% |
| Unknown (for use in program evaluation only)[[217]](#footnote-219) | 66% |

kWh\_heatingElectric = If electric heat (resistance or heat pump), reduction in annual electric heating due to attic insulation

= ((((1/R\_old - 1/R\_attic) \* A\_attic \* (1-Framing\_factor\_attic)) \* 24 \* HDD) / (ηHeat \* 3412)) \* ADJAtticElectricHeat\*%ElectricHeat

HDD = Heating Degree Days

 = Dependent on location:[[218]](#footnote-220)

| **Climate Zone****(City based upon)** | **HDD 60** |
| --- | --- |
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[[219]](#footnote-221) | 4,860 |

ηHeat = Efficiency of heating system

= Actual (where new or where it is possible to measure or reasonably estimate). If not available refer to default table below:[[220]](#footnote-222)

|  |  |  |  |
| --- | --- | --- | --- |
| **System Type** | **Age of Equipment** | **HSPF Estimate** | **ηHeat (Effective COP Estimate)= (HSPF/3.413)\*0.85** |
| Heat Pump | Before 2006 | 6.8 | 1.7 |
| 2006 - 2014 | 7.7 | 1.92 |
| 2015 on  | 8.2 | 2.04 |
| Resistance | N/A | N/A | 1 |
| Unknown (for use in program evaluation only)[[221]](#footnote-223) | N/A | N/A | 1.28 |

3412 = Converts Btu to kWh

ADJAtticElectricHeat = Adjustment for electric heating savings to account for inaccuracies in engineering algorithms[[222]](#footnote-224)

 = 60%

%ElectricHeat = Percent of homes that have electric space heating

| **Heating System** | **%ElectricHeat** |
| --- | --- |
| Electric resistance or heat pump | 100% |
| Natural Gas  | 0% |
| Unknown heating fuel (for use in program evaluation only)[[223]](#footnote-225) | 13% |

**For example:** energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

Assume a non-income eligible single family home in Chicago installs 700 ft2 of attic insulation, completes air sealing, has 10.5 SEER Central AC and 2.26 (1.92 including distribution losses) COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWh = (ΔkWh\_cooling + ΔkWh\_heating)

= (((((1/5 - 1/38) \* 700 \* (1-0.07)) \* 842 \* 0.75 \* 24)/ (1000 \* 10.5)) \* 121% \* 100% \* 100%) + (((((1/5 - 1/38) \* 700 \* (1-0.07)) \* 5113 \* 24) / (1.92 \* 3412)) \* 60% \* 100%)

= 197 + 1,271

= 1,468 kWh

ΔkWh\_heatingGas = If gas *furnace* heat, kWh savings for reduction in fan run time

 = ΔTherms \* Fe \* 29.3 \* ADJAtticHeatFan

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

 = 3.14%[[224]](#footnote-226)

29.3 = kWh per therm

ADJAtticHeatFan = Adjustment for fan savings to account for innacuracies in engineering algorithms[[225]](#footnote-227)

 = 107%

**For example:** energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

Assume a non-income eligible single family home in Chicago installs 700 ft2 of attic insulation, completes air sealing, has a gas furnace with system efficiency of 66% (for therm calculation see Natural Gas Savings section), and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWh = 147 \* 0.0314 \* 29.3 \* 107%

= 145 kWh

###### Summer Coincident Peak Demand Savings

ΔkW = (ΔkWh\_cooling / FLH\_cooling) \* CF

Where:

FLH\_cooling = Full load hours of air conditioning

= Dependent on location as below:[[226]](#footnote-229)

|  |  |  |
| --- | --- | --- |
| **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[[227]](#footnote-230) | 629 | 564 |

Use Multifamily if: Building has shared HVAC or meets utility’s definition for multifamily

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

 = 68%[[228]](#footnote-231)

CFSSP = Summer System Peak Coincidence Factor for Heat Pumps (during system peak hour)

 72%%[[229]](#footnote-232)

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

= 46.6%[[230]](#footnote-233)

**For example:** energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

Assume a non-income eligible single family home in Chicago installs 700 ft2 of attic insulation, has 10.5 SEER Central AC and 2.26 COP Heat Pump, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔkWSSP = 197 / 570 \* 0.68

= 0.24 kW

ΔkWPJM = 168 / 570 \* 0.466

= 0.16 kW

###### Natural Gas Savings

If Natural Gas heating:

ΔTherms = ((((1/R\_old - 1/R\_attic) \* A\_attic \* (1-Framing\_factor\_attic)) \* 24 \* HDD) / (ηHeat \* 100,000 Btu/therm) \* ADJAtticGasHeat \* IENetCorrection\*%GasHeat

Where:

HDD = Heating Degree Days

 = Dependent on location:[[231]](#footnote-234)

|  |  |
| --- | --- |
| **Climate Zone****(City based upon)** | **HDD 60** |
| 1 (Rockford) | 5,352 |
| 2 (Chicago) | 5,113 |
| 3 (Springfield) | 4,379 |
| 4 (Belleville) | 3,378 |
| 5 (Marion) | 3,438 |
| Weighted Average[[232]](#footnote-235) | 4,860 |

ηHeat = Efficiency of heating system

= Equipment efficiency \* distribution efficiency

= Actual (where new or where it is possible to measure or reasonably estimate).[[233]](#footnote-236) If not available, use 72% for existing system efficiency.[[234]](#footnote-237)

ADJAtticGasHeat = Adjustment for gas heating savings to account for inaccuracies in engineering algorithms[[235]](#footnote-238)

 = 72%

IENetCorrection = 100% if not income eligible or attic insulation is installed without air sealing

= 110% if installing air sealing and attic insulation in income eligible projects with a deemed NTG value of 1.0 to offset net savings adjustment inherent when using ADJAtticGasHeat of 72% [[236]](#footnote-239)

%GasHeat = Percent of homes that have gas space heating

| **Heating System** | **%GasHeat** |
| --- | --- |
| Electric resistance or heat pump | 0% |
| Natural Gas  | 100% |
| Unknown heating fuel (for use in program evaluation only)[[237]](#footnote-240) | 87% |

Other factors as defined above.

**For example:** energy savings from ceiling/attic insulation. Energy savings for air sealing are included in a separate example in Section 5.6.1: Air Sealing.

Assume a non-income eligible single family home in Chicago installs 700 ft2 of attic insulation, has a gas furnace with system efficiency of 66%, and has pre and post attic insulation R-values of R-5 and R-38, respectively:

ΔTherms = ((((1/5 - 1/38) \* 700 \* (1-0.07)) \* 24 \* 5113) / (0.66 \* 100,000)) \* 72% \* 100% \* 100%

= 151 therms

**Mid-Life adjustment**

In order to account for the likely replacement of existing heating and cooling equipment during the lifetime of this measure, a mid-life adjustment should be applied. To calculate the adjustment, re-calculate the savings above using the following new baseline system efficiency assumptions:

| **Efficiency Assumption** | **System Type** | **New Baseline Efficiency** |
| --- | --- | --- |
| ηCool       | Central AC | 13 SEER |
| Heat Pump | 14 SEER |
| ηHeat | Electric Resistance | 1.0 COP |
| Heat Pump(8.2HSPF/3.413)\*0.85 | 2.04 COP |
| Furnace90% AFUE \* 0.85 | 76.5% AFUE |
| Boiler | 82% AFUE |

This reduced annual savings should be applied following the assumed remaining useful life of the existing equipment, estimate to be 10 years or 13 years for boilers.[[238]](#footnote-241) Note if the existing equipment efficiency is greater than the new baseline efficiency listed above, do not apply a mid-life adjustment.

###### Water Impact Descriptions and Calculation

N/A

###### Deemed O&M Cost Adjustment Calculation

N/A

###### Measure Code: RS-SHL-AINS-V04-210101

###### Review Deadline: 1/1/2024

1. All Residential sized Federal Standards are from DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431. [↑](#footnote-ref-1)
2. It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline. [↑](#footnote-ref-2)
3. Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1. [↑](#footnote-ref-3)
4. DEER 08, EUL\_Summary\_10-1-08.xls. [↑](#footnote-ref-4)
5. Ohio Technical Reference Manual 8/2/2010 referencing CenterPoint Energy-Triennial CIP/DSM Plan 2010-2012 Report; Additional reference stating >20 years is soured from the US DOE Energy Savers for Tankless or Demand-Type Water Heaters. [↑](#footnote-ref-5)
6. Ibid. [↑](#footnote-ref-6)
7. Cost information is based upon data from “2010-2012 WA017 Ex Ante Measure Cost Study Draft Report”, Itron, February 28, 2014. See “NR HW Heater\_WA017\_MCS Results Matrix - Volume I.xls” for more information. [↑](#footnote-ref-7)
8. Act on Energy Commercial Technical Reference Manual, Table 9.6.1-4 [↑](#footnote-ref-8)
9. Act on Energy Technical Reference Manual, Table 9.6.2-3 [↑](#footnote-ref-9)
10. Minnesota Center for Energy and Environment, Low contractor estimate used to reflect less labor required in new construction of venting. [↑](#footnote-ref-10)
11. Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads. [↑](#footnote-ref-11)
12. US DOE Building America Program, Building America Analysis Spreadsheet (for Chicago, IL), Office of Energy Efficiency & Renewable Energy. [↑](#footnote-ref-12)
13. Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%. [↑](#footnote-ref-13)
14. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-14)
15. Methodology based on Cadmus analysis. Annual hot water usage in gallons based on CBECS (2012) and RECS (2009) consumption data of East North Central (removed outliers of 1,000 kBtuh or less) to calculate hot water usage. Annual hot water gallons per tank size gallons based on the tank sizing methodology found in ASHRAE 2011 HVAC Applications. Chapter 50 Service Water Heating. Demand assumptions (gallons per day) for each building type based on ASHRAE Chapter 50 and to LBNL White Paper. LBL-37398 Technology Data Characterizing Water Heating in Commercial Buildings: Application to End Use Forecasting. Assumes hot water heater efficiency of 80%. [↑](#footnote-ref-15)
16. According to CBECS 2012 “Lodging” buildings include Dormitories, Hotels, Motel or Inns and other Lodging and “Nursing” buildings include Assisted Living and Nursing Homes. [↑](#footnote-ref-16)
17. All Residential sized Federal Standards are from DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431. [↑](#footnote-ref-17)
18. It is assumed that tanks <75,000Btu/h and >55 gallons will not be eligible measures due to the high baseline. [↑](#footnote-ref-18)
19. Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1. [↑](#footnote-ref-19)
20. Full load hours assumption based on Wh/Max W Ratio from Itron eShape data for Missouri, calibrated to Illinois loads. [↑](#footnote-ref-20)
21. Coincidence factor based on Average W in peak period/Max W from Itron eShape data for Missouri, calibrated to Illinois loads. [↑](#footnote-ref-21)
22. All Residential sized Federal Standards are from DOE Standard 10 CFR 430, Residential-Duty and Commercial Federal Standard are from DOE Standard 10 CFR 431. [↑](#footnote-ref-22)
23. Definitions provided in 10 CFR 430, Subpart B, Appendix E, Section 5.4.1. [↑](#footnote-ref-23)
24. Water heaters (WH) require annual maintenance. There are different levels of effort for annual maintenance depending if the unit is gas or electric, tanked or tankless. Electric and gas tank water heater manufacturers recommend an annual tank drain to clear sediments. Also recommended are “periodic” inspections by qualified service professionals of operating controls, heating element and wiring for electric WHs and thermostat, burner, relief valve internal flue-way and venting systems for gas WHs. Tankless WH require annual maintenance by licensed professionals to clean control compartments, burners, venting system and heat exchangers. This information is from WH manufacturer product brochures including GE, Rennai, Rheem, Takagi and Kenmore. References for incremental O&M costs were not found. Therefore the incremental cost of the additional annual maintenance for tankless WH is estimated at $100. [↑](#footnote-ref-24)
25. A full description of the ComEd model development is found in “ComEd Portfolio Modeling Report. Energy Center of Wisconsin July 30, 2010”. [↑](#footnote-ref-25)
26. Based on model with single duct reheat system with a fixed outdoor air volume. [↑](#footnote-ref-26)
27. Based on model with single duct reheat system with airside economizer controls, with constant volume zone reheat boxes and single speed fan motors. [↑](#footnote-ref-27)
28. Based on model with single duct reheat system with airside economizer controls, zone VAV reheat boxes and VFD fan motors. [↑](#footnote-ref-28)
29. Source paper is the CLEAResult "Steam Traps Revision #1" dated August 2011. Primary studies used to prepare the source paper include Enbridge Steam Trap Survey, KW Engineering Steam Trap Survey, Enbridge Steam Saver Program 2005, Armstrong Steam Trap Survey, DOE Federal Energy Management Program Steam Trap Performance Assessment, Oak Ridge National Laboratory Steam System Survey Guide, KEMA Evaluation of PG&E's Steam Trap Program, Sept. 2007. Communication with vendors suggested an inverted bucket steam trap life typically in the range of 5 - 7 years, float and thermostatic traps 4- 6 years, float and thermodynamic disc traps of 1 - 3 years. Cost does not include installation. [↑](#footnote-ref-29)
30. “Venturi Steam Trap – Functional Laboratory Study, GTI on behalf of Illinois utilities, Nicor Gas, Peoples Gas, and North Shore Gas, and on behalf of contributing utilities from other states, March 26, 2019. This report reflects phase 1 of an ongoing field study that will continue data collection to validate useful life and provide information on proper sizing in various end use applications. Additional data expected in 2021. [↑](#footnote-ref-30)
31. Ibid. Based on reported age for venturi steam traps currently operating in the field. [↑](#footnote-ref-31)
32. Ibid. [↑](#footnote-ref-32)
33. This factor include 2571 kWh/MG for water supply based on Illinois energy intensity data from a 2012 ISAWWA study. For more information please review Elevate Energy’s ‘IL TRM: Energy per Gallon Factor, May 2018 paper’. Note since the water loss associated with this measure is due to evaporation and does not discharge into the wastewater system, only the water supply factor is used here. [↑](#footnote-ref-33)
34. See “Derivation of Equation for Subsonic Compressible Flow through an Orifice and Supporting Calculations for Illinois TRM Steam Trap Measure” paper for more information. [↑](#footnote-ref-34)
35. Enbridge adjustment factor used as referenced in CLEAResult “Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012 and DOE Federal Energy Management Program Steam Trap Performance Assessment. [↑](#footnote-ref-35)
36. Medium and high pressure steam trap inlet pressure based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours. Dry cleaning steam trap inlet pressure based on C5 Steam Traps – Nicor FINAL 10.27.11. [↑](#footnote-ref-36)
37. For applications where inlet pressures and orifice diameters are provided in the table, default values are directly calculated using the equation above. For applications where inlet pressures and orifice diameters are not provided in the table, default values are assumptions based on engineering judgement and will be revisited in future years. [↑](#footnote-ref-37)
38. Heat of vaporization of steam at the inlet pressure to the steam trap. Implicit assumption that the average boiler nominal pressure where the vaporization occurs, is essentially that same pressure. Referenced in CLEAResult “Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012. [↑](#footnote-ref-38)
39. US DOE Building America Program. Building America Analysis Spreadsheet. For Chicago, IL. [↑](#footnote-ref-39)
40. Ibid. [↑](#footnote-ref-40)
41. Katrakis, J. and T.S. Zawacki. “Field-Measured Seasonal Efficiency of Intermediate-sized Low-Pressure Steam Boilers”. ASHRAE V99, pt. 2, 1993. [↑](#footnote-ref-41)
42. Medium and high-pressure steam trap annual operating hours based on Navigant analysis of source collected during program implementation by Nicor Gas for GPY1 through GPY4. For each steam trap project, the data provided measure savings description, operating pressure, installation Zip code, business building type, program year, and annual operating hours. [↑](#footnote-ref-42)
43. Dry cleaners survey data as referenced in CLEAResult “Work Paper Steam Traps Revision #2" Revision 3 dated March 2, 2012. [↑](#footnote-ref-43)
44. ”Gates Corporation Announces New EPDM Molded Notch V-Belts,” The Gates Rubber Co., June 2010 (Assumed 3% efficiency improvement). [↑](#footnote-ref-44)
45. “Synchronous Belt Drives Offer Low Cost Energy Savings,” Baldor. February 2009. (attached in Reference Documents). [↑](#footnote-ref-45)
46. "Energy Savings from Synchronous Belts," The Gates Rubber Co., February 2014. (Assumed 5% efficiency improvement). [↑](#footnote-ref-46)
47. “Motor System Tip Sheet #5, Replace V-Belts with Cogged or Synchronous Belt Drives,” USDOE-EERE, September 2005. (Assumed 2% efficiency improvement). [↑](#footnote-ref-47)
48. ComEd Trm June 1, 2010 page 139. The Office hours is based upon occupancy from the eQuest model developed for EFLH, since it was agreed the ComEd value was too low. [↑](#footnote-ref-48)
49. “DEER2014-EUL-table-update\_2014-02-05.xlsx,” Database for Energy Efficiency Resources (DEER), DEER2014 EUL Table. (attached in Reference Documents). [↑](#footnote-ref-49)
50. Grainger catalog on-line web-site for Dayton v-belt pricing. [↑](#footnote-ref-50)
51. Assumed to be $150 based on mechanical contractor estimate. [↑](#footnote-ref-51)
52. Note that kWConnected may be determined using various methodologies. The examples provided use rated HP and assumed load factor. Other methodologies include rated voltage and full load current with assumed load factor, or actual measured voltage and current. [↑](#footnote-ref-52)
53. Com Ed TRM June 1, 2010. [↑](#footnote-ref-53)
54. Efficiency values for motors less than one HP taken from Baldor Electric Catalog 501, standard motor product catalog. [↑](#footnote-ref-54)
55. Hours per year are estimated using the eQuest models as the total number of hours the fans are operating for heating, cooling and ventilation for each building type. [↑](#footnote-ref-55)
56. Based on information found in Advanced Manufacturing Office, US DOE, “Replace V-Belts with Notched or Synchronous Drives”, (US Department of Energy Motor Systems Tip Sheet #5, DOE/GO-102012-3740, November 2012). V-belt drives can have a peak efficiency of 95% and synchronous belts operate at 98%, therefore ESF is (1-95%/98%) = 3.1%. [↑](#footnote-ref-56)
57. Based on analysis of Itron eShape data for Missouri, calibrated to Illinois loads, supplied by Ameren. The AC load during the utility’s peak hour is divided by the maximum AC load during the year. [↑](#footnote-ref-57)
58. 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. [↑](#footnote-ref-58)
59. This is a consistent assumption with 5.2.2 Advanced Power Strip – Tier 2. [↑](#footnote-ref-59)
60. Price survey performed by Illume Advising LLC for IL TRM workpaper, see “Current Surge Protector Costs and Comparison 7-2016” spreadsheet. [↑](#footnote-ref-60)
61. 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. [↑](#footnote-ref-61)
62. NYSERDA Measure Characterization for Advanced Power Strips. Study based on review of:

Smart Strip Electrical Savings and Usability, Power Smart Engineering, October 27, 2008.

Final Field Research Report, Ecos Consulting, October 31, 2006. Prepared for California Energy Commission’s PIER Program.

Developing and Testing Low Power Mode Measurement Methods, Lawrence Berkeley National Laboratory (LBNL), September 2004. Prepared for California Energy Commission’s Public Interest Energy Research (PIER) Program.

2005 Intrusive Residential Standby Survey Report, Energy Efficient Strategies, March 2006.

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

“Smart strip” in this context refers to the category of Advanced Power Strips, does not specifically signify Smart Strip® from BITS Limited, and was used without permission. Smart Strip® is a registered trademark of BITS Smart Strip, LLC. [↑](#footnote-ref-62)
63. Opinion Dynamics and Navigant. Impact Evaluation for ComEd 2018 site visit efforts for leave-behind measures in public housing multi-family units. The Evaluation Team completed site visits for 72 apartment units across seven of the ten participating properties in which advanced power strips were installed. The Evaluation Team attempted a census using all data provided at the time of site visit planning (Fall 2018). The program distributed a total of 476 advanced power strips, with 471 distributed amongst the seven properties with completed site visits. The Team performed intrasite sampling within each property and verified a total of 37 advanced power strips of the 92 within the sample. [↑](#footnote-ref-63)
64. Research from 2018 ComEd Home Energy Assessment participant survey. [↑](#footnote-ref-64)
65. Research from 2018 Ameren Illinois Income Qualified participant survey. [↑](#footnote-ref-65)
66. Research from 2019 ComEd Appliance Rebate Program- Online Marketplace participant survey [↑](#footnote-ref-66)
67. Calculated as average of 5 and 7 plug savings assumptions. [↑](#footnote-ref-67)
68. Average of hours for controlled TV and computer from; NYSERDA Measure Characterization for Advanced Power Strips [↑](#footnote-ref-68)
69. 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. [↑](#footnote-ref-69)
70. Calculated as average of 5 and 7 plug savings assumptions. [↑](#footnote-ref-70)
71. 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. [↑](#footnote-ref-71)
72. The ENERGY STAR program released version 1.0 of its Connected Thermostats Specification in 2017. Details and active discussion can be found on ENERGY STAR website; ‘Connected Thermostats Specifications v1.0’.  [↑](#footnote-ref-72)
73. 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. [↑](#footnote-ref-73)
74. 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 [↑](#footnote-ref-74)
75. Based on Opinion Dynamics Corporation, “ComEd Residential Saturation/End Use, Market Penetration & Behavioral Study”, Appendix 3: Detailed Mail Survey Results, p34, April 2013. [↑](#footnote-ref-75)
76. Based on 2017 Residential Smart Thermostat Workpaper, prepared by SCE and Nest for SCE (Work Paper SCE17HC054, Revision #0). Estimate ability of smart systems to continue providing savings after disconnection and conduct statistical survival analysis which yields 9.2-13.8 year range. [↑](#footnote-ref-76)
77. 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.  [↑](#footnote-ref-77)
78. Including any one-time software integration or annual software maintenance, and or individual device energy feature fees. [↑](#footnote-ref-78)
79. 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 $150 and $250, excluding the availability of time or market-limited wholesale or volume pricing. The assumed incremental cost is based on the middle of this range ($175) 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. [↑](#footnote-ref-79)
80. 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). [↑](#footnote-ref-80)
81. 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.) [↑](#footnote-ref-81)
82. 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. [↑](#footnote-ref-82)
83. Value used is based on known PY8 percent of electric heat provided by Navigant as part of the ongoing evaluation work source: “Slide 21: May 22, 2018, Second Addendum IL TRM Advanced Thermostat Cooling Savings Evaluation” [↑](#footnote-ref-83)
84. 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 0.03412) 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\_08222018.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. [↑](#footnote-ref-84)
85. 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. [↑](#footnote-ref-85)
86. This estimate is based on a consumption data analysis with matching to non-participants and is therefore net with respect to participant spillover and between net and gross with respect to free ridership. Like all consumption data analyses, it is gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to these factors will be determined as part of the annual SAG net-to-gross process. [↑](#footnote-ref-86)
87. 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’), and incorporate any inherent in service rate impact. These values are adjusted upwards in v9 to account for inclusion of Thermostat Optimization savings in an estimated 40% of future participants (based on reported share of Nest and ecobee participants and 2020 rates of Thermostat Optimization and including an assumed 90% ISR consistent with the Guidehouse cooling savings study). The basis for the Thermostat Optimization savings is Navigant “ComEd CY2018 Seasonal Savings Heating Season Impact Evaluation Report”, March 2019.

These values are used as the basis for the weighted average savings value when the type of existing thermostat is not known. Using weightings updated from PY8 data, based upon baseline type, and allocating programmability into manual and programmable based upon programmed status yields a weighted new blend of 43% manual (or non-programmed programmable) and 57% programmed. Further evaluation and regular review of this key assumption is encouraged. [↑](#footnote-ref-87)
88. Since mobile homes are similar to Multifamily homes with respect to conditioned floor area but to single-family homes with respect to exposure (i.e., all four wall orientations are adjacent to the outside), this factor is estimated as an average of the single family and multifamily household factors. [↑](#footnote-ref-88)
89. 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 [↑](#footnote-ref-89)
90. Program-specific household factors may be utilized on the basis of sufficiently validated program evaluations. [↑](#footnote-ref-90)
91. When Household type is unknown, a value of 96.5% may be used as a weighted average of 90% SF and 10% MF (96.5% = 100%\*90% + 65%\*10%) based on a Navigant evaluation of PY8 participants in ComEd’s advanced thermostat program. [↑](#footnote-ref-91)
92. 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. [↑](#footnote-ref-92)
93. 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 STARversion 3 criteria for 2% Fe. See “Programmable Thermostats Furnace Fan Analysis.xlsx” for reference. [↑](#footnote-ref-94)
94. 99% of ComEd PY8 program participants (AC targeted programs) have Central AC per communication with Navigant’s ongoing 2017/2018 cooling savings evaluation. Non-targeted programs are still expected to have participation with %AC above general population rates. 82.5% is an average of the 99% program participation rate, and the 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 ; [↑](#footnote-ref-95)
95. When both climate zone and home type are unknown, a value of 623 hours may be used as a weighted average of 90% SF and 10% MF (623 = 629\*90% + 564\*10%) based on a Navigant evaluation of PY8 participants in ComEd’s advanced thermostat program. [↑](#footnote-ref-96)
96. 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. [↑](#footnote-ref-97)
97. Ibid. [↑](#footnote-ref-98)
98. *All-Electric Homes PY6 Metering Results: Multifamily HVAC Systems*, Cadmus, October 2015 [↑](#footnote-ref-99)
99. Weighted based on number of residential occupied housing units in each zone. [↑](#footnote-ref-100)
100. Actual unit size required for Multifamily building, no size assumption provided because the unit size and resulting savings can vary greatly depending on the number of units. [↑](#footnote-ref-101)
101. Single family cooling capacity based on Final Evaluation Report: Central Air Conditioning Efficiency Services (CACES), October 19, 2010, ComEd, Navigant Consulting. Multifamily capacity based on weighted average of PY9 Ameren and ComEd MF cooling capacities. Mobile home capacity based on ENERGY STAR’s Manufactured Home Cooling Equipment Sizing Guidelines which vary by climate zone and home size. The average size of a mobile home in the East North Central region (1,120 square feet) from the 2015 RECS data is used to calculated appropriate size. [↑](#footnote-ref-102)
102. Unknown is based on statewide weighted average of 90% single family and 10% multifamily, based on a Navigant evaluation of PY8 participants in ComEd’s advanced thermostat program. [↑](#footnote-ref-103)
103. Estimate based upon Navigant, 2018 “EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case” [↑](#footnote-ref-104)
104. Note that “Cooling\_Reduction” percentage is the savings expected from reduced cooling use, and is not the same as % cooling savings that are based on total kWh saved (including fan and heating kWh savings) as a percent of total kWh used for cooling. [↑](#footnote-ref-105)
105. The Cooling\_Reduction assumption is based on a TAC agreement to weight the consumption data analysis result (econometric) and the adjusted ENERGY STAR method for estimating runtime savings for advanced thermostats with stakeholder assumptions about baseline behavior (ENERGY STAR), provided by Guidehouse in 2020. The econometric result (7.8%) is weighted at 90%, and the ENERGY STAR result (10-14% range taken as reasonable by stakeholders, however 14% is used to account for increased Thermostat Optimization) weighted at 10%.

This econometric value is based upon the non-weather normalized savings percentage, adjusted for selection bias, %AC and ISR, with additional adjustment to account for the anticipated growth in Thermostat Optimization savings, from 12% of participants in the study to 45% of future participants (based on reported share of Nest and ecobee participants and 2020 rates of Thermostat Optimization). The basis for the Thermostat Optimization savings is Navigant’s “ComEd CY2018 Seasonal Savings Cooling Season Impact Evaluation Report”, March 2019. The estimate of cooling reduction factor includes an adjustment for apparent selection bias, per stakeholder request as part of a 2020 study by Guidehouse involving a consumption analysis of ComEd advanced thermostat rebate recipients. Guidehouse acknowledges that this adjustment is a coarse method of addressing potential bias, but believes that this adjustment may not be accurate or applicable for future studies of this type.

The adjusted ENERGY STAR analysis is gross with respect to all components of net-to-gross (free ridership, and participant and non-participant spillover). The econometric analysis uses matching to future participants and is therefore gross with respect to free ridership. Like all consumption data analyses, it is net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to these factors will be determined as part of the annual SAG net-to-gross process. [↑](#footnote-ref-106)
106. The 2020 Guidehouse evaluation indicated that 6.75% of participants installed the advanced thermostat out of state. An additional reduction is applied to account for purchases that are never installed. Based on the available data this is estimated as an additional 3.75%. [↑](#footnote-ref-107)
107. The current Cooling\_DemandReduction assumption is based on results presented on August 4th, 2020 from a Guidehouse econometric analysis and further refinements discussed throughout August.

The final value is based upon the non-weather normalized savings percentage, adjusted for selection bias, %AC and ISR, provided by the Guidehouse econometric results, and includes an additional adjustment to account for the anticipated growth in Thermostat Optimization savings, The estimate of cooling reduction factor includes an adjustment for apparent selection bias, per stakeholder request  as part of a 2020 study by Guidehouse involving a consumption analysis of ComEd advanced thermostat rebate recipients. Guidehouse acknowledges that this adjustment is a coarse method of addressing potential bias, but believes that this adjustment may not be accurate or applicable for future studies of this type. [↑](#footnote-ref-108)
108. From Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder. [↑](#footnote-ref-109)
109. Based on converting SEER assumption to EER. [↑](#footnote-ref-110)
110. 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.) [↑](#footnote-ref-111)
111. 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.) [↑](#footnote-ref-112)
112. Value used is based on known PY8 percent of electric heat provided by Navigant as part of the ongoing evaluation work source: “Slide 21: May 22, 2018, Second Addendum IL TRM Advanced Thermostat Cooling Savings Evaluation” [↑](#footnote-ref-113)
113. Values are based on adjusting the average household heating consumption (849 therms) for Chicago based on ‘Table 3-4, Program Sample Analysis, Nicor R29 Res Rebate Evaluation Report 092611\_REV FINAL to Nicor’, calculating inferred heating load by dividing by average efficiency of new in program units in the study (94.4%) and then applying standard assumption of existing unit efficiency of 83% (estimate based on 24% of furnaces purchased in Illinois were condensing in 2000 (based on data from GAMA, provided to Department of Energy), assuming typical efficiencies: (0.24\*0.92) + (0.76\*0.8) = 0.83). This Chicago value was then adjusted to a statewide average using relative HDD assumptions to adjust for the evaluation results focus on northern region. Values for individual cities are then calculated by comparing average HDD to the individual city’s HDD. [↑](#footnote-ref-114)
114. RES v C&I split is based on a weighted (by sales volume) average of ComEd PY8, PY9 and CY2018 and Ameren PY8 in store intercept survey results. See ‘RESvCI Split\_2019.xlsx’. [↑](#footnote-ref-115)
115. US Department of Energy, “Energy Savings Forecast of Solid State Lighting in General Illumination Applications”, December 2019. The resultant forecast is provided on the SharePoint site “Lamp Forecast Workbook.xls”. [↑](#footnote-ref-116)
116. Navigant and Itron, “CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations”. [↑](#footnote-ref-117)
117. 30% of the respondents at the three Income Eligible Program stores where in-store intercepts were conducted met ComEd’s income eligible definition; Navigant and Itron, “CY2018 ComEd Income Eligible Product Discounts – Lighting NTG Recommendations”. [↑](#footnote-ref-118)
118. Based on recommendation in the Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics Corporation; NEEP Emerging Technology Research Report, p 6-18. [↑](#footnote-ref-119)
119. Representing a third of the expected lamp lifetime. [↑](#footnote-ref-120)
120. 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. [↑](#footnote-ref-121)
121. Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs. [↑](#footnote-ref-122)
122. Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for screw-based omnidirectional LEDs in exterior applications. [↑](#footnote-ref-123)
123. Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study. [↑](#footnote-ref-124)
124. See file “LED baseline and EE wattage table\_2018.xlsx” for details on lamp wattage calculations. [↑](#footnote-ref-125)
125. Based on ENERGY STAR V2.1 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. [↑](#footnote-ref-126)
126. Final ISR assumptions for efficiency kits are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, capped at 95%, and second and third year estimates based on same proportion of future installs. 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. [↑](#footnote-ref-127)
127. 1st year in service rate is based upon analysis of ComEd PY8, PY9 and CY2018 and Ameren PY8 intercept data (see ‘RES Lighting ISR\_2019.xlsx’ for more information). [↑](#footnote-ref-128)
128. 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. [↑](#footnote-ref-129)
129. Based upon average of Navigant low income single family direct install field work LED ISR and 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. [↑](#footnote-ref-130)
130. 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. [↑](#footnote-ref-131)
131. Free bulbs provided without request, with little or no education. Consistent with Standard CFL assumptions. [↑](#footnote-ref-132)
132. 1st year ISR for school kits based on ComEd PY9 data for the Elementary Energy Education program. Final ISR assumptions are based upon comparing with CFL Distribution First year ISR and multiplying by the CFL Distribution Final ISR value, and second and third year estimates based on same proportion of future installs. [↑](#footnote-ref-133)
133. Opt-in program to receive kits via mail, with little or no education. Consistent with Standard CFL assumptions. [↑](#footnote-ref-134)
134. Research from 2018 Ameren Illinois Income Qualified participant survey. [↑](#footnote-ref-135)
135. Kits distributed in a community setting, targeted to income qualified communities. Research from 2018 Ameren Illinois Income Qualified participant survey. [↑](#footnote-ref-136)
136. Free bulbs provided through local food banks and food pantries. [↑](#footnote-ref-137)
137. 1st year ISR is determined based on online surveys conduted for ComEd CY2018 Food Bank LED Distribution program. See ‘CY2018 ComEd Foodbank LED Dist Survey Results\_Navigant’. [↑](#footnote-ref-138)
138. In the absence of any program specific data, 98% lifetime ISR assumption is made based on similarity between 1st year ISR values with the Retail (Time of Sale) program and the 2nd and 3rd year installations are scaled accordingly. [↑](#footnote-ref-139)
139. 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. [↑](#footnote-ref-140)
140. Leakage rate is based upon review of PY8-CY2018 evaluations from ComEd and PY8 for Ameren. [↑](#footnote-ref-141)
141. Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs. [↑](#footnote-ref-142)
142. Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. The IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide hours of use for screw-based omnidirectional LEDs in exterior applications. [↑](#footnote-ref-143)
143. Based on a weighted average of hours of use in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study. [↑](#footnote-ref-144)
144. 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) [↑](#footnote-ref-145)
145. 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) [↑](#footnote-ref-146)
146. Unknown is weighted average of interior v exterior (assuming 5% exterior lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009. [↑](#footnote-ref-147)
147. Negative value because this is an increase in heating consumption due to the efficient lighting. [↑](#footnote-ref-148)
148. 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. [↑](#footnote-ref-149)
149. Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study. [↑](#footnote-ref-150)
150. 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. [↑](#footnote-ref-151)
151. 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. [↑](#footnote-ref-152)
152. 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. [↑](#footnote-ref-153)
153. 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) [↑](#footnote-ref-154)
154. Unknown is weighted average of interior v exterior (assuming 5% exterior lighting based on distribution of LEDs from on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study) and SF v MF interior based on statewide weighted average of 69% single family and 31% multifamily, based on IL data from 2009 RECS Table HC2.9 Structural and Geographic Characteristics of Homes in Midwest Region, Divisions and States, 2009. [↑](#footnote-ref-155)
155. Based on the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs. [↑](#footnote-ref-156)
156. Based on lighting logger study conducted as part of the PY5/6 ComEd Residential Lighting Program evaluation. the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs was unable to provide coincidence factors for screw-based omnidirectional LEDs in exterior applications. [↑](#footnote-ref-157)
157. Based on a weighted average of coincidence factors in interior and exterior applications, assuming 5% exterior lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study. [↑](#footnote-ref-158)
158. Average result from REMRate modeling of several different configurations and IL locations of homes [↑](#footnote-ref-159)
159. Based on a weighted average of interior and exterior hours of use from the IL Statewide LED Lighting Logger study conducted as part of the PY8/PY9 evaluations of the Ameren Illinois and ComEd Residential Lighting programs, assuming 15% exterior specialty lighting. The distribution of LEDs is based on the on-site lighting inventory conducted as part of the IL Statewide LED Lighting Logger study. [↑](#footnote-ref-160)
160. This has been estimated assuming that natural gas central furnace heating is typical for Illinois residences (66% of Illinois homes have a Natural Gas Furnace (based on Energy Information Administration, 2009 Residential Energy Consumption Survey)

In 2000, 24% of furnaces purchased in Illinois were condensing (based on data from GAMA, provided to Department of Energy during the federal standard setting process for residential heating equipment - see Furnace Penetration.xls). Furnaces tend to last up to 20 years and so units purchased 10 years ago provide a reasonable proxy for the current mix of furnaces in the State. Assuming typical efficiencies for condensing and non-condensing furnaces and duct losses, the average heating system efficiency is estimated as follows:

(0.24\*0.92) + (0.76\*0.8) \* (1-0.15) = 0.70 [↑](#footnote-ref-161)
161. See “Lamp Forecast Workbook\_2020.xlsx” for calculation. [↑](#footnote-ref-162)
162. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-163)
163. This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems. [↑](#footnote-ref-164)
164. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-165)
165. 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)’. [↑](#footnote-ref-166)
166. 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. [↑](#footnote-ref-167)
167. 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, *Exegisis 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”. [↑](#footnote-ref-168)
168. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 65°F. [↑](#footnote-ref-169)
169. 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. [↑](#footnote-ref-170)
170. 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. [↑](#footnote-ref-171)
171. Derived by calculating the sensible and total loads in each hour. For more information see Bruce Harley, CLEAResult “Infiltration Factor Calculations Methodology.doc”. [↑](#footnote-ref-172)
172. As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company.

These adjustment factors are based on a consumption data analysis using matching to non-participants. The values are therefore between net and gross with respect to free ridership. Like all consumption data analyses, they are net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to the savings will be determined as part of the annual SAG net-to-gross process. [↑](#footnote-ref-173)
173. The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0. [↑](#footnote-ref-174)
174. Percentage of homes in Illinois that have central cooling from “Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009” from Energy Information Administration, 2009 Residential Energy Consumption Survey [↑](#footnote-ref-175)
175. 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, *Exegisis 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”. [↑](#footnote-ref-176)
176. National Climatic Data Center, calculated from 1981-2010 climate normals with a base temp of 60°F. [↑](#footnote-ref-177)
177. 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. [↑](#footnote-ref-178)
178. 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. [↑](#footnote-ref-179)
179. Based on Illinois data from “Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009” from Energy Information Administration, 2009 Residential Energy Consumption Survey [↑](#footnote-ref-180)
180. 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. [↑](#footnote-ref-181)
181. As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. These adjustment factors are based on a consumption data analysis using matching to non-participants. The values are therefore between net and gross with respect to free ridership. Like all consumption data analyses, they are net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to the savings will be determined as part of the annual SAG net-to-gross process. [↑](#footnote-ref-182)
182. Prescriptive savings are based upon “Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps).” Middletown, CT: KEMA, 2010. Accessed July 30, 2015, and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See ‘Rx Airsealing HDD adjustment.xls’ for more information. [↑](#footnote-ref-184)
183. Prescriptive savings are based upon “Cost Benefit Analysis for 2018, Annual Report submitted to Virginia Natural Gas, Inc., submitted by Nexant.” July 31, 2018. Adjusted for relative HDD of Virginia Beach VA with the IL climate zones. See “Window Film Savings Calculation.xlsx” for more information. [↑](#footnote-ref-185)
184. 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. [↑](#footnote-ref-186)
185. ILLUME Advising LLC. School-Based Energy Education Programs: Goals, Challenges, and Opportunities. October 2015. See result for AEP Ohio Weather stripping/door sweep/gaskets kit in table on page 17. [↑](#footnote-ref-187)
186. For residential showerheads and aerators in the IL-TRM, the ratio of ISRs for opt-in kits to ISRs for distributed school kits vary from 1.9 to 2.4. For weatherization kits, opt-in ISRs are estimate at 1.5 times the distributed school ISR. [↑](#footnote-ref-188)
187. 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. [↑](#footnote-ref-189)
188. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-190)
189. 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)’. [↑](#footnote-ref-191)
190. 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. [↑](#footnote-ref-192)
191. 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, *Exegisis 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”. [↑](#footnote-ref-193)
192. 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.. [↑](#footnote-ref-194)
193. 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: (see ‘BPI Distribution Efficiency Table’) or by performing duct blaster testing. [↑](#footnote-ref-195)
194. Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses. [↑](#footnote-ref-196)
195. As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. These adjustment factors are based on a consumption data analysis using matching to non-participants. The values are therefore between net and gross with respect to free ridership. Like all consumption data analyses, they are net with respect to participant spillover and gross with respect to non-participant spillover. For more detail, see Table 5-3 in Volume 4 of the IL-TRM. Consistent with Section 7.2 of the Illinois EE Policy Manual, applicable net-to-gross adjustments to the savings will be determined as part of the annual SAG net-to-gross process. [↑](#footnote-ref-197)
196. The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0. [↑](#footnote-ref-198)
197. Based on Illinois data from “Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009” from Energy Information Administration, 2009 Residential Energy Consumption Survey [↑](#footnote-ref-199)
198. Prescriptive savings are based upon “Evaluation of the Weatherization Residential Assistance Partnership and Helps Programs (WRAP/Helps).” Middletown, CT: KEMA, 2010. Accessed July 30, 2015, and adjusted for relative HDD of Bridgeport/Hartford CT with the IL climate zones. See ‘Rx Airsealing HDD adjustment.xls’ for more information. [↑](#footnote-ref-200)
199. Prescriptive savings are based upon “Cost Benefit Analysis for 2018, Annual Report submitted to Virginia Natural Gas, Inc., submitted by Nexant.” July 31, 2018. Adjusted for relative HDD of Virginia Beach VA with the IL climate zones. See “Window Film Savings Calculation.xlsx” for more information. [↑](#footnote-ref-201)
200. 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. [↑](#footnote-ref-202)
201. ILLUME Advising LLC. School-Based Energy Education Programs: Goals, Challenges, and Opportunities. October 2015. See result for AEP Ohio Weather stripping/door sweep/gaskets kit in table on page 17. [↑](#footnote-ref-203)
202. For residential showerheads and aerators in the IL-TRM, the ratio of ISRs for opt-in kits to ISRs for distributed school kits vary from 1.9 to 2.4. For weatherization kits, opt-in ISRs are estimate at 1.5 times the distributed school ISR. [↑](#footnote-ref-204)
203. This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems. [↑](#footnote-ref-205)
204. As recommended in Navigant ‘ComEd Effective Useful Life Research Report’, May 2018. [↑](#footnote-ref-206)
205. This is intentionally longer than the assumptions found in the early replacement measures as the application of this measure will occur in a variety of homes that will not be targeted for early replacement HVAC systems. [↑](#footnote-ref-207)
206. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-208)
207. 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)’. [↑](#footnote-ref-209)
208. 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. [↑](#footnote-ref-210)
209. Component estimate of airfilm above and below, sheathing and sheet rock, (0.68+0.5+0.45+0.68 = 2.3) is rounded up to R-3. [↑](#footnote-ref-211)
210. Ibid. [↑](#footnote-ref-212)
211. 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. [↑](#footnote-ref-213)
212. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-214)
213. 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. [↑](#footnote-ref-215)
214. 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. [↑](#footnote-ref-216)
215. As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. Adjustment factor was derived from a consumption data regression analysis with an experimental design that does not require further net savings adjustment for non-income eligible populations. [↑](#footnote-ref-217)
216. The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0. [↑](#footnote-ref-218)
217. Percentage of homes in Illinois that have central cooling from “Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009” from Energy Information Administration, 2009 Residential Energy Consumption Survey [↑](#footnote-ref-219)
218. 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. [↑](#footnote-ref-220)
219. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-221)
220. 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. [↑](#footnote-ref-222)
221. 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. [↑](#footnote-ref-223)
222. As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. [↑](#footnote-ref-224)
223. Based on Illinois data from “Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009” from Energy Information Administration, 2009 Residential Energy Consumption Survey [↑](#footnote-ref-225)
224. 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. [↑](#footnote-ref-226)
225. As demonstrated in air sealing and insulation research by Navigant, see Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. Adjustment factor was derived from a consumption data regression analysis with an experimental design that does not require further net savings adjustment for non-income eligible populations. [↑](#footnote-ref-227)
226. 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. [↑](#footnote-ref-229)
227. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-230)
228. Based on metering of 24 homes with central AC during PY4 and PY5 in Ameren Illinois service territory. [↑](#footnote-ref-231)
229. 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)’. [↑](#footnote-ref-232)
230. 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. [↑](#footnote-ref-233)
231. 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. [↑](#footnote-ref-234)
232. Weighted based on number of occupied residential housing units in each zone. [↑](#footnote-ref-235)
233. 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: (see ‘BPI Distribution Efficiency Table’) or by performing duct blaster testing. [↑](#footnote-ref-236)
234. Based on average Nicor PY4 nameplate efficiencies derated by 15% for distribution losses. [↑](#footnote-ref-237)
235. As demonstrated in air sealing and insulation research by Navigant, Navigant (2018). C*omEd and Nicor Gas Air Sealing and Insulation Research Report.* Presented to Commonwealth Edison Company and Nicor Gas Company. Adjustment factor was derived from a consumption data regression analysis with an experimental design that does not require further net savings adjustment for non-income eligible populations. [↑](#footnote-ref-238)
236. The additional value of 10% was selected to acknowledge that some portion of the regression-derived adjustment factors accounts for gross impact effects, and that removing net effects embedded in the adjustment factors would increase savings to some degree. A review of historical NTG values for air sealing and insulation measures in non-income eligible populations did not provide definitive guidance for estimating the net component of the adjustment factors. Historically, free ridership has ranged from 9% to 26% for like measures, and spillover has ranged from 1% to 14%, while NTGs have ranged from 0.75 to 1.05. The midpoint of the NTG range would be 0.90, a 10% reduction from 1.0. [↑](#footnote-ref-239)
237. Based on Illinois data from “Table HC7.9 Air Conditioning in Homes in Midwest Region, Divisions, and States, 2009” from Energy Information Administration, 2009 Residential Energy Consumption Survey [↑](#footnote-ref-240)
238. This is intentionally longer than the assumption found in the early replacement measures as the application of this measure will occur in a variety of homes and will not be targeting those homes appropriate for early replacement HVAC systems. [↑](#footnote-ref-241)